



Guidance Notes No.7

Electrical Waterbath Stunning of Poultry

Published by

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ISBN 978-1-871561-44-9

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WARNING: DISCLAIMER OF LIABILITY

These guidance notes are intended for all persons around the world who may need to humanely slaughter animals. In conjunction with reading the principles of operation described in these guidance notes, readers are responsible for consulting the relevant legislation. It is not possible to include in this guide the legal requirements of every country or area.

This guide is intended to instruct operators in the proper and humane use of equipment for handling, stunning and killing animals. In order to do this and to safeguard the welfare of the animals to be killed, it is necessary for the guide to be both thorough and illustrated. As such, the following pages may contain descriptions and images of dead animals or stunned animals in the process of dying. The material is presented in an objective and professional manner but please do not read further if you feel you may be negatively affected by the content.

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The HSA is not responsible for the content of external websites or publications referenced within these guidance notes (eg in the *Useful contacts and publications* section), nor do those external publications necessarily reflect the views of the HSA.

Livestock handling and killing systems are potentially dangerous. You are advised to follow your employer's recommendations and procedures with particular care. If you are in any doubt as to any aspect of the safe operation of systems for handling, transporting, stunning and killing animals, you should consult your manager and the manufacturer. In no circumstances can the HSA accept any liability for the way in which systems are used, or for any loss, damage, death or injury caused thereby, since this depends on circumstances wholly outside of the HSA's control.

The HSA aims to provide up-to-date and accurate information. If you have suggestions for the content of this guide please inform the HSA via info@hsa.org.uk or using the contact details provided at www.hsa.org.uk

The Humane Slaughter Association (HSA) is the only registered charity that works, in the UK and internationally, through educational, scientific and technical advances, exclusively towards the highest worldwide standards of welfare for food animals during transport, marketing, slaughter and killing for disease control and welfare reasons.



Legislation

Some areas and countries of the world have instated legislation to protect the welfare of animals during slaughter and killing. For example, in Europe the key legislation is:

Council Regulation (EC) No. 1099/2009 on the protection of animals at the time of killing, which has applied since 1 January 2013.

The major provision of the European regulation is that **animals shall be spared any avoidable pain, distress or suffering during their killing and related operations (eg handling, lairage, restraint, stunning and bleeding)**.

Around the world, there may be variation between the legal requirements of some areas or countries. For example:

- The possibility to implement stricter national rules under Article 26 of EC Regulation 1099/2009 means that member states of the European Union may differ in some aspects of their national legislation protecting animal welfare at the time of killing.
- In the United Kingdom, each of the separate countries (ie England, Northern Ireland, Scotland and Wales) may, through their devolved administrations, implement separate national legislation to deal with aspects of the European law.

It is therefore critical that readers of these guidance notes are aware of all the rules in their country of operation, and any country to which they export products, because it is not feasible to list them all in this document. Where possible, to assist readers, some references are made to European law.

When used within the text for the first time, individual words that are printed in **bold** are defined in the *Glossary* at the end of these guidance notes.



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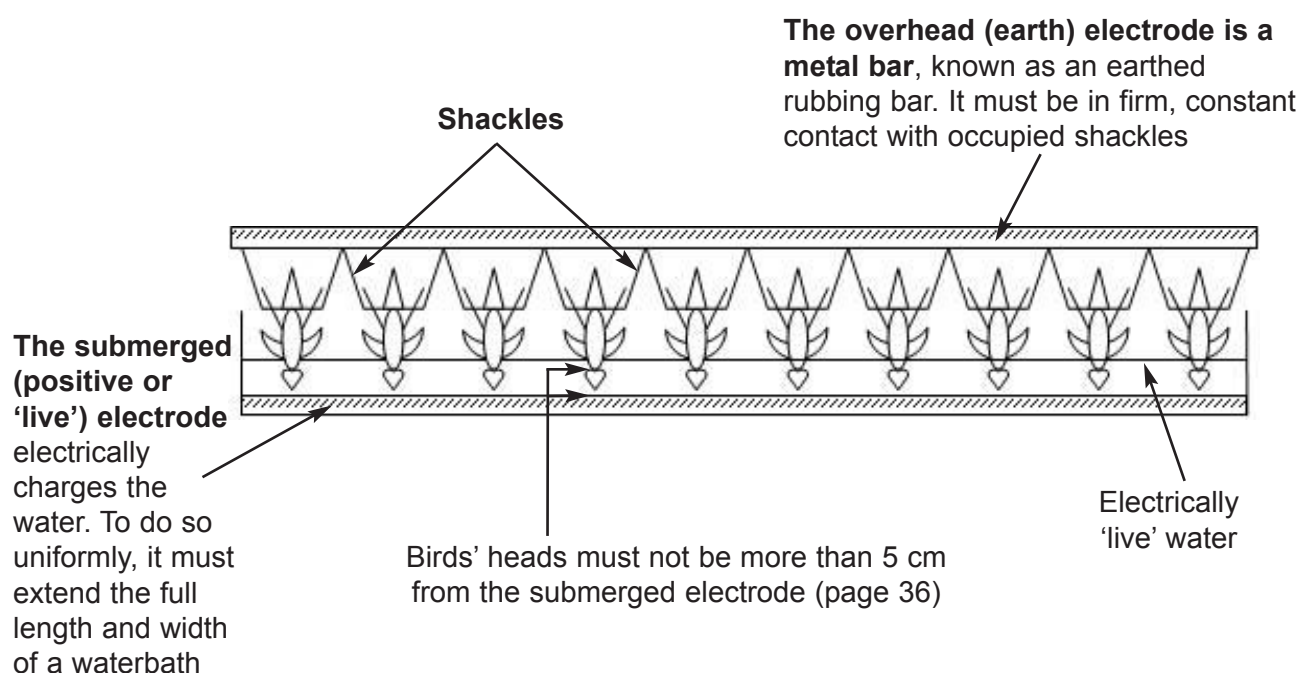


Components and principle of function of an electrical waterbath

Every year millions of birds are reared for food for humans and the **slaughter** of these birds must be carried out in a way that causes no avoidable pain or suffering. Several systems have been developed to facilitate the humane stunning of poultry. The main principle of these methods is to **stun** each bird so that it becomes unconscious and therefore **insensible** to pain; this condition must persist until the bird is dead.

Large-scale abattoirs stun poultry using either electrical waterbath or controlled atmosphere systems. Electrical waterbaths are the most commonly used commercial stunning method (eg in the European Union: Agra CEAS, 2012). Birds are unloaded from their transport containers, inverted and hung by both legs, at the shank, onto a moving shackle line which conveys them to an electrical waterbath (Figure 1). An electric potential difference must be generated across the circuit to produce a steady flow of **current** that overcomes the total resistance, including that of the birds (Bilgili, 1992). In a conventional system, the **electrode** submerged in the water is maintained at a higher electric potential than the earthed rubbing bar (Bilgili, 1992; Sparrey *et al*, 1993). When the head of a bird enters the electrified water, the electrical circuit is completed and the electric potential difference causes the electrons, and therefore the current, to flow from the submerged electrode in the waterbath up through the water and through the head of the bird, through its body and legs, to the metal shackle in which the bird is restrained and finally up into the earthed rubbing bar.

Figure 1. Principle components of a conventional multi-bird electrical waterbath



The aim of electrical stunning is to pass sufficient current through the brain in order to disrupt its normal function and immediately render the animal unconscious (**electronarcosis**) and insensible to pain until death supervenes. The electrical



parameters (**voltage**, current, **frequency** and **waveform**) of a waterbath system can be set to either stun or stun-kill the birds. A bird may be electrically stun-killed by applying a current at a frequency and **amplitude** that causes unconsciousness *and* simultaneously stimulates cardiac muscle into **ventricular fibrillation** and causes death by **cardiac arrest**. Alternatively, a bird can be electrically stunned and then **killed** by **exsanguination** (blood loss due to severance of the major blood vessels between the heart and the brain). No matter whether a system is intended to achieve a stun or a stun-kill, as soon as possible after they exit a waterbath, all stunned birds should have their two common carotid arteries severed, preferably by using a **ventral neck cut** to sever all the major blood vessels ventral to the spine and to enable easy post-cut verification of which blood vessels are severed. Prompt and accurate neck cutting will benefit animal welfare and meat quality.

Despite the increasing complexity and highly-automated operation of some stunning and killing equipment, it remains the responsibility of the operator to ensure that *every* bird is humanely stunned and killed. Humane electrical stunning of animals requires a sound understanding of electrical parameters, their influence on an animal's brain and how to deliver those parameters efficiently. Effective waterbath stunning depends on the control and management of several elements in order to maximise bird welfare. The welfare of poultry is directly affected by many variables including the waveform and frequency of an electric current, the amount (amplitude or magnitude) of current applied to each individual bird, the optimisation of the flow of electrical current through each bird and the time, and quality, of neck cutting. Waterbaths must be appropriately designed, manufactured, installed and maintained in order to ensure consistent, effective stunning, rendering birds immediately unconscious. Poorly maintained, or incorrectly used, electrical equipment can result in extreme suffering for an animal and may also compromise operator safety. The pre-slaughter management and handling of all birds must also be carried out in such a way as to prevent avoidable pain, distress and damage to the bird and to the carcass.

These guidance notes explain how to optimise bird welfare during pre-slaughter handling, the theory and the practice of using electrical waterbaths to stun birds and how to effectively bleed birds once they are stunned. These notes:

- Provide comprehensive, essential technical information to abattoir personnel who are responsible for protecting bird welfare and/or for those who teach others how to protect bird welfare (eg persons who train people for proficiency qualifications or for Certificates of Competence in animal welfare at slaughter). In particular, the guidance is aimed at supervisors, animal welfare officers, managers, official veterinarians, meat inspection officers and maintenance engineers. (An HSA online guide is also available from www.hsa.org.uk which summarises these guidance notes for abattoir personnel who may not require as much detailed information for their particular role.)
- Provide background information on the slaughter methods to help readers to understand the technology and to perform their jobs competently and safely.
- Provide guidance on equipment design to assist management with the selection of equipment for humane slaughter.
- Provide guidance on the setting-up and maintenance of equipment.



- Describe faults and conditions that might prevent equipment operating correctly.
- Explain how to rectify common problems.

Within these guidance notes there are discussions of potential ways in which bird welfare might be improved; these are included as food-for-thought for those who might be interested in trialling such potential improvements. However, some of the associated technology or principles may be in their infancy. In addition, electrical waterbath slaughter systems are complex. Therefore, it is important to be aware that any changes made to one aspect of an existing blueprint or system (with the aim of solving a problem and/or generally improving bird welfare) may potentially be accompanied by new problems (perhaps even elsewhere along the slaughter line), some of which may possibly have a detrimental effect on bird welfare. Therefore, small-scale trials of any changes and careful monitoring of the outcome for bird welfare along the entire live-bird slaughter line are necessary, to ensure detection of any new problems that might have been introduced or detection of any existing problems that may have worsened.

A note of caution

Different slaughter methods may have different advantages and disadvantages for animal welfare and meat quality. The conventional electrical waterbath is not a preferred stunning method for poultry welfare because:

- There are inherent risks to animal welfare associated with inversion and shackling of conscious birds.
- It is difficult to control the effectiveness of the stun for every individual bird processed, eg to prevent pre-stun shocks, to ensure immediate immersion of the head in the electrified water and to prevent individual birds entirely avoiding the electrified water.
- Commercial waterbath systems generally accommodate a number of birds simultaneously and are operated at a constant voltage, which makes it difficult to deliver the correct current amplitude to each bird. EFSA (2004) stated: “*equipment manufacturers should develop [constant current] systems that are cost effective and commercially viable*”.
- Scientific research has reported that “*...effective stunning [parameters] using the conventional waterbath almost exclusively produces blood splashing [in the meat]...*” (Hindle *et al*, 2010). This may partly be due to the estimate that “*only a small proportion of current applied in a water bath may flow through the brain and the majority may flow through the carcass*”, which is likely to pose problems for welfare *and* meat quality (EFSA, 2004).

The 2012 EFSA scientific opinion on electrical requirements for waterbath stunning recommended that “*unless the problems...for all existing waterbath stunning methods can be resolved, other stunning methods should be used*”. Therefore the world requires improved methods of stunning (electrical or otherwise), to guarantee better parameters for animal welfare and a higher quality carcass.



In the meantime, operating conventional electrical waterbath stunners to a high standard is critical for poultry welfare. In line with the HSA aim to provide information on good operational practices, which may reduce the risk of potential animal welfare problems, these guidance notes include advice that prioritises animal welfare, based as much as possible on scientific evidence.

[At the time of publication of this document, the alternative large-scale slaughter methods for poultry were controlled atmosphere systems (CAS). CAS may not be perfect for animal welfare but does offer significant advantages for poultry welfare (and staff health and safety) compared to electrical waterbaths, by avoiding the need for abattoir staff to directly handle, invert and shackle conscious birds and every bird is stunned by a well-run CAS system. To read more about CAS systems, please view HSA publications at www.hsa.org.uk]

The HSA welcomes evidence-based comments that may be suitable to update the content of HSA publications. In the case of electrical stunning, this particularly includes further evidence on:

- improved ways of assessing birds for the effectiveness of stunning
- which electrical parameters are better for inducing unconsciousness in 100% of birds
- the status of the availability of true constant current stunners



Pre-slaughter handling & restraint

To slaughter birds humanely and effectively, they must be presented to the stunning and killing equipment in the correct manner. The heads of all the birds should be positioned so that the waterbath and neck cutting equipment are applied easily, accurately and for the appropriate duration of time. Restraint facilitates this by restricting a bird's movement. Shackles are the method of restraint used with conventional electrical waterbaths and wet plate whole-body electrical stunners for poultry.

The shackling environment

The shackling area should be well-ventilated, dry and as draught- and dust-free as possible. Blue (Prayitno *et al*, 1994) or low-intensity lighting (eg 5 lux: Jones *et al*, 1998) may minimise struggling in birds during shackling; however light levels must also be sufficient for human health and safety and for monitoring bird welfare. Noise and any other possible sources of disturbance to live birds must be minimised. In particular, loud, sudden, abrupt noises may unsettle and panic birds (OIE, 2014); so metal gates should be baffled, radios should not be excessively loud and personnel should avoid shouting (especially whilst handling birds).

Shackling staff should be rotated to other duties at regular intervals to prevent operator fatigue and/or diminished concentration which may hamper their ability to safeguard bird welfare.

When the time comes to shackle a particular batch of birds, their transport container(s) should be re-located from the lairage so they are as close as possible to the shackle line. Containers should be arranged so shacklers can easily reach into them, retrieve a bird and shackle it, without being forced to adopt awkward postures. Containers can be elevated so shacklers do not have to bend to reach birds. Consideration should be given to the number of birds, the typical weight of a bird and the distance it must be lifted and carried by the operators, from a container to the shackle hang-on point.

A container should only be opened as much as is necessary for each person to remove one bird at a time; this limits the opportunities for birds, particularly agile and/or nervous types, to escape. If birds escape from containers or their shackles, they must be immediately retrieved using good practice catching techniques. Birds must not be allowed to wander around an abattoir because this may put them at risk of injury by vehicles. Shackling stations can be caged to prevent escaped birds from roaming into the lairage. Netting can be suspended above the shackling area to contain any escaped individuals of species that can fly (eg guinea fowl). Net threads should be thick and the mesh size should not be too large or too small, to avoid a situation where a bird becomes entangled in the net and needs to be cut free. It may also be useful to have a hand-held catching net in the shackling station to quickly retrieve any bird that proves difficult to capture by hand.

“Animals shall not be shackled if they are too small for the waterbath stunner or if shackling is likely to induce or increase the pain suffered.”

European Council (EC) Regulation No. 1099/2009

Some poultry are susceptible to gait abnormalities due to rapid growth rate, developmental deformities and infectious causes. In addition, catching poultry on-



Pre-slaughter handling & restraint

farm for transport to slaughter may result in new injuries, particularly if birds are caught, lifted and carried by a single leg and carried in one hand with other birds (Gregory & Austin, 1992; Gregory *et al*, 1992). Any injured or otherwise unfit birds must be humanely killed on-farm (not transported to an abattoir for routine killing). At the abattoir, it is important that shacklers monitor the birds they unload and do not shackle any injured, diseased or relatively small (eg runt) individuals. Instead, such birds should be killed using a humane back-up stunning device (eg mechanical percussive (captive-bolt) stunner), which must always be nearby and available to the operators for immediate use.

If any apparently unconscious or apparently dead birds are discovered in containers at the time of unloading, operators should first confirm whether the bird is unconscious or dead. (Warm birds may be alive but unconscious and they should be assessed for indicators of life (breathing, corneal reflex). Cold-stressed birds can sometimes be cold-to-the-touch and stiff but may still be conscious and/or alive. Their breathing is likely to be of a very slow rhythm; checking whether they display a positive corneal reflex is likely to be a good method of assessing their condition.) If a bird is unconscious and it cannot be processed for consumption, personnel should dislocate the bird's neck to ensure it dies, before disposing of the bird. Similarly, if a bird appears to be dead (cold) but if there is uncertainty as to whether it is actually dead, personnel should dislocate the bird's neck to ensure it is dead, before disposing of the bird.

Companies may wish to consider adopting a system for personnel to record how many sick, injured or dead birds arrive at the unloading point. An animal welfare officer (AWO) should review the records. (Designating a few members of staff as AWOs is advisable for good practice and in some parts of the world AWOs are a legal requirement, eg in Europe.) The OIE (2014) advises that fewer than 1 – 2% of chickens should have broken or dislocated wings. If any patterns are identified that suggest a particular supplier, catching team or haulier are associated with unusual levels of unfit birds, then an investigation can be launched. When there is a high rate of rejected birds, dead-on-arrivals (DOAs) or dead-on-shackling birds (birds thought to have died between arriving at the abattoir and the time of shackling for slaughter), a veterinarian should *post-mortem* a sample of birds to attempt to determine the cause(s) of any trauma and the cause(s) of death (Grist, 2013). Companies should also investigate the possible reasons why some flocks have unusually good quality birds; such information may potentially provide new management strategies that might be suitable for other sites.

Handling for shackling

It is important that personnel responsible for unloading and shackling birds are trained to competently protect the welfare of each bird they handle. Animals may be stressed by humans handling them, particularly if the animals are unfamiliar or inexperienced with such contact and/or with a handling process (Beuving & Blokhuis, 1997). Birds may already be under some stress following the on-farm catching procedure and subsequent transport. At the abattoir, exposure to any additional stressors should be avoided or minimised in order to reduce bird activity, protect them from physical injury and to keep any animal communication of potential stress to an absolute minimum. This can be achieved by limiting the amount of handling and ensuring the handling procedures do not arouse panic in the birds. Personnel must work in a manner which reduces risk of injury to themselves and to the bird, and which minimises any fear a bird may experience. For example, Table 1 lists actions shacklers should 'aim to'



Pre-slaughter handling & restraint

achieve and actions to 'avoid'. Rough handling can result in distress, alarm vocalisations, increased bird activity, bruises, broken bones and dislocated joints, all of which influence the ultimate quality of the carcass.

Although it is not preferred for animal welfare, if birds are unloaded *en masse* and conveyed to a shackling point, the conveyor systems must be constructed so as to prevent any part of a bird becoming trapped and there must be no obstructions that birds might collide with during carriage. Conveyors must allow birds to maintain their balance, ie birds should be able to maintain an upright posture during carriage, without flapping. To achieve this, conveyors must be kept at shallow angles, have non-slip surfaces and move in a smooth manner, without jolting. Abattoirs must be appropriately designed so there is no need to transfer birds between conveyors; transfer can result in flapping and potential for injury.

Table 1. Shackling poultry.

Aim to:	Avoid:
secure any latches that hold open container doors, so doors cannot drop down onto birds during unloading. Faulty latches or doors that do not remain open must be immediately repaired or replaced.	tipping conscious poultry out of containers; tipping may induce additional stress, fear, flapping and potential for injury (eg red wing tips as a result of flapping (Gregory <i>et al</i> , 1989) and birds may scratch one another with their toenails during, and after, the fall as they try to regain stability and an upright posture.
using both hands, lift one bird at-a-time from a container and shackle it immediately.	roughly or unnecessarily moving birds around containers to position them for lifting.
handle birds calmly and quietly; gently reach under, or around the sides of, a bird to locate its legs in one movement.	knocking any part of a bird against objects, eg transport containers.
once both legs are held, slowly and gently lift up the legs, whilst gently lowering the bird onto its breast. This should reduce any swinging motion and minimise the risk of leg or pelvic injuries (particularly important with heavy birds).	a) pulling a bird across a transport container floor; it may flap (risk of wing, pelvic or leg injuries) and if the container floor is perforated or damaged, toe or breast injuries (and associated carcass damage) may result, respectively; b) lifting a bird off a supporting surface (eg transport container floor) until both legs are held. (Otherwise the bird may swing through the air and may flap.)
a) after lifting by both legs, gently insert each leg into a separate slot of the shackle (with the bird's weight evenly distributed between both legs); b) gently lower the bird's breast against the breast contact strip.	a) lifting, carrying or shackling a bird by one leg, the head, tail or wing(s); b) allowing a shackled bird to 'fall' against the breast contact strip; it may stimulate flapping; c) trapping a bird's toes between its leg and the shackle.



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The shackle line

“Shackles shall be wet before live birds are shackled and exposed to the current. Birds shall be hung by both legs.”

European Council (EC) Regulation No. 1099/2009

“The size and shape of the metal shackles shall be appropriate to the size of the legs of poultry to be slaughtered so that electrical contact can be secured without causing pain.” EC Regulation 1099/2009*

*abattoirs with relevant equipment that was in use prior to 1 January 2013 have until 8 December 2019 to comply with Article 14(1) and Annex II of Regulation 1099/2009, including the requirement above. (Abattoirs, layouts or equipment constructed after 1 January 2013 must apply the requirements immediately.)

The shackles should be well-maintained and wetted immediately prior to shackling a bird. Shackles have the potential to compress the tissues of the shank, including the **innervated periosteum** and the tarsometatarsal bone, which is potentially painful for a conscious animal (Gentle & Tilston, 2000) and may cause damage (Figure 2a), indicating poor animal welfare. Therefore abattoirs must use shackles that have the correct size (gauge) slot for the birds' legs. Larger, heavier birds are likely to have legs with a larger diameter/circumference (eg male broiler chickens: Parker *et al*, 1997). Shackles with tapering slots are preferable to parallel-slot shackles. If an abattoir processes different species, types, sexes or sizes of bird, then shackles with multiple slots of varying tapering gauges should be installed, to allow birds to be shackled according to their size, thereby limiting (to a degree) leg compression. The pressure required to compress a broiler chicken's leg into a shackle was shown to increase exponentially with the deformation; increasing the shackle slot gauge by even 1 mm

Figure 2a. Shackling damage (bruising indicated by arrows) to the shanks of chickens. Compression damage may also be indicated by residual indentation in a leg at a shackle contact point and a smoother surface to the skin in that indentation (Schofield *et al*, 2009 unpublished).



Figure 2b. Prototype compliant shackle (left) and a standard shackle (right). The internal struts of the compliant shackle move (indicated by arrows) to accommodate the width of a bird's leg. Image: J Lines.





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significantly reduces the pressure (Sparrey, 1994). Compliant shackles were developed to ease pressure on birds' legs whilst allowing sufficient restraint and electrical contact (Figure 2b: Lines *et al*, 2012); however the supporting research is in its infancy.

Shacklers must not use excessive force when loading a bird into a shackle, because this may cause further compression of the legs. It can be difficult to determine the sex of some types of birds (eg broiler chickens), especially when shackling them at fast line speeds. In such circumstances, and if abattoirs use multi-slot/gauge shackles, it may be appropriate to slaughter males and females separately so shacklers can be instructed, in advance, which shackle slot to use. For example, males can be shackled in the larger slot and females in the smaller slot. However, shacklers should be encouraged to use their initiative also and, as appropriate, shackle a large female or a small male bird in a larger or smaller slot, respectively. During further processing, birds' legs should be examined for bruising of the thigh muscle and shanks and/or for bone breaks. Consistent bruising may imply the shackle gauge is too small for certain bird types and/or that operators are forcing birds' legs into the shackle, which is neither good for animal welfare nor carcass quality (Raj, 2004). (Bear in mind that on-farm catching damage may cause similar defects.) Although a shackle should not cause compression injuries or pain, the fit should be sufficiently firm to prevent excessive movement or escape and to allow for good electrical contact for stunning (Prinz, 2009).

Shackling imposes a greater load on birds' legs as bird weight increases (EFSA, 2004). For this reason, heavy birds (eg exceeding 15 kg live weight) should not be shackled for waterbath stunning but should instead be slaughtered using an alternative humane restraint, stunning and killing method (eg restraint cone and captive-bolt followed by exsanguination).

Maximum durations that conscious birds can remain suspended in shackles before waterbath stunning, according to EC Regulation 1099/2009*:

**Two minutes for ducks, geese and turkeys
One minute for all other species of poultry**

*abattoirs with relevant equipment that was in use prior to 1 January 2013 have until 8 December 2019 to comply with Article 14(1) and Annex II of Regulation 1099/2009, including the requirement above. (Abattoirs, layouts or equipment constructed after 1 January 2013 must apply the requirements immediately.)

Involuntary inversion appears to cause poultry stress (Kannan & Mench, 1996). It is not their default stance and birds do not have diaphragms, so inversion may feel uncomfortable if the viscera compress the heart and lungs. For this reason, and because shackling conscious birds may be painful, it is necessary to minimise the duration that birds are inverted and restrained on a shackle line. Whilst it may sometimes be necessary to allow a short time for birds to reduce their activity and settle down on a shackle line (so they enter the waterbath calmly and smoothly, reducing the risk of pre-stun shocks), the suspension time should always be as short as possible. For example, EFSA (2004) and the OIE (2014) recommended a maximum shackling time of one minute but EFSA (2004) reported 12 or 20 seconds may be sufficient time for chickens and turkeys respectively, to settle on a shackle



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line. Abattoirs should self-assess their facilities and strive to reduce shackling durations, without causing welfare problems in other areas of the system. Breast support conveyors (read the section '**Methods of reducing bird activity on a shackle line**') may assist in this goal.

Shackle lines must be designed to minimise disturbance of suspended birds. Ideally, all sections of a shackle line conveying conscious birds must be straight (ie no corners) and without inclines, whether ascents or descents (Kannan *et al*, 1997). A shackled bird must be kept clear of any obstructions that might cause panic, struggling, pain or injury, including when a bird's neck and wings are fully outstretched and if it flaps. Obstructions may include neighbouring birds; if a flapping bird hits its neighbour(s) with its wings, the neighbour(s) may also be disturbed and begin flapping. Shackle lines must be constructed and maintained so they do not jolt birds because this is likely to stimulate flapping (Kannan *et al*, 1997; EFSA, 2004). Shackle line speeds must be of a pace that does not cause the birds to struggle. Fast line speeds may cause birds to notice inclines, to swing round any corners (if corners still exist on some shackle lines) and to lose contact with the breast contact strip, initiating wing flapping. The line speed must also be appropriate for each operator to safely, comfortably, gently and effectively shackle and thereafter, whenever necessary, tend to a bird on the shackle line (eg back-up stun/kill it or remove it from the shackle), without undue haste. At a given line speed, there must be a sufficient number of shacklers so that each has sufficient time to identify, separate and kill (or immediately pass to another appropriate person to kill) any birds that are unfit to undergo the routine slaughter method (Sparrey, 1994). All operators responsible for poultry welfare must always be able to visually monitor shackled birds, but it is better if a shackle line is not in such close proximity to operators (or to thoroughfares for other personnel) that their routine working movements disturb shackled birds (Wotton & Wilkins, 2004).

The controls of all processing equipment should be immediately accessible, should the need arise to stop the shackle line in an emergency. For example, multiple emergency-stop buttons or a pull-cord spanning the entire length of a shackle line (from the shackling station to the scald-tank) will allow personnel to immediately stop the line and raise the alarm. Personnel should be encouraged to activate these emergency-stop systems if they foresee or witness an emergency (eg a live bird entering a scald-tank or plucker). Correspondingly, the whole length of a shackle line from the hang-on point furthest from the waterbath, to the point of entry into the scald-tank must be readily accessible to abattoir personnel, should any bird need immediate attention.

If a line stops and conscious birds are likely to be suspended for longer than the recommended or legal maximum duration, they should be immediately stunned and killed, in their shackles, using a humane back-up method. It is preferred, for bird welfare, to stun and kill birds in their shackles, to avoid the additional handling (which may compound any stress) and the potential discomfort (eg recompression of the legs) if birds are either unshackled and then killed using a back-up method, or if they are unshackled, recrated and later reshackled (on potentially damaged legs) for waterbath stunning, once the system restarts.

Methods of reducing bird activity on a shackle line

Ideally there should be no flapping on a shackle line, or as little as possible (Jones *et al*, 1998); however, lack of flapping does not necessarily indicate a bird is unstressed (Kannan *et al*, 1997). Handling, inversion, the act of shackling and tight shackles may



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induce stress, pain and flapping, which may lead to dislocations (particularly of the wings), fractures and muscle haemorrhages (EFSA, 2004). Struggling may adversely affect meat quality by depleting adenine triphosphate (ATP) and glycogen in the breast muscle (Satterlee *et al*, 2000). This produces a build-up of lactic acid in the muscle, resulting in a low muscle pH, which reduces the water-holding capacity of the meat (eg Berri *et al*, 2005). So, in addition to its welfare importance, there is a financial incentive in encouraging birds to limit their activity as much as possible.

“A system in contact with the breast of the birds shall be built from the point of shackling until the birds enter the waterbath stunner...”

EC Regulation 1099/2009*

*abattoirs with relevant equipment that was in use prior to 1 January 2013 have until 8 December 2019 to comply with Article 14(1) and Annex II of Regulation 1099/2009, including the requirement above. (Abattoirs, layouts or equipment constructed after 1 January 2013 must apply the requirements immediately.)

A breast contact strip can be installed to run in-parallel with a shackle line. Also referred to as breast ‘comforters’, they are commonly used to reduce the incidence of wing flapping (Kettlewell & Hallworth, 1990; Bilgili, 1992; Jones *et al*, 1998). A breast contact strip should extend below each bird’s head (Figure 3a) and the strip must be in constant and full contact with every bird’s breast along the entire length of the line, from the furthest point for shackling, until a bird enters the electrified water (Figure 3b) (Wotton & Wilkins, 2004). This is easier to achieve if the shackle line is straight but if it is not, the strip must also extend around any bends. The contact strip should be made of one solid piece of non-conductive material, to avoid feathers becoming trapped in joints between sections of material (which may cause discomfort or hold back the body, relative to the legs and shackle, which may cause the bird to swing



Figure 3a. Broiler chickens on a shackle line with a breast contact strip. The contact strip extends below the birds’ heads, restricting their visual field, so they are less likely to be disturbed by activity around them.



Figure 3b. Breast contact strips should extend up to the waterbath entrance, as shown in this image. Contact strips should be made of one piece of material and should not have joints that may disturb birds as they move over it. This image shows two joints (indicated by arrows) which are not smooth and should be replaced with a single piece of material.



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sideways when released). The material should be rigid to ensure heavier birds do not distort the strip which may prevent lighter-weight birds making effective contact (Wotton & Wilkins, 2004). Contact strips should be sufficiently tall and adjustable so their height and angle can be suited to every type of bird slaughtered at the abattoir. Slightly angling a contact strip may create greater contact with birds' chests, which may be particularly important for small birds or for flighty birds that tend to pull their chests away from the strip whilst flapping. If they are to work effectively, breast contact strips must be repaired or replaced if the surface of the material begins to wear or become uneven (eg buckle).

Flapping may tend to occur when birds are loaded into the shackles and for a short time thereafter (Gregory & Bell, 1987; Kannan *et al*, 1997). To prevent this, it was suggested that, immediately after the shackling action, a shackler should routinely either run their hands down a bird's body or briefly hold onto the bird's legs (Gregory & Bell, 1987) - care must be taken not to scratch or squeeze a bird, or its legs, during this process in case it exacerbates any disturbance. If a bird shows potential signs of distress, such as excessive wing flapping or excessive vocalising, it should be tended to immediately, eg an operator's hand should be gently placed on the bird's breast, or the bird should be gently held against the breast contact strip, whilst allowing it to move with the advancing shackle line (otherwise, when the handler lets go, the bird may swing sideways and cause it to resume flapping). If this does not stop the struggling, the bird should be stunned and killed immediately using a humane back-up method, preferably before it is removed from the shackle. The shackle and the shackle line should be examined for possible causes of the disturbance. Different types of birds can differ in their activity levels whilst on a shackle line, eg slow-growing chickens had a shorter latency to more intense struggling compared to fast-growing and heavy lines of chicken; and heavy-line chickens were less active than fast-growing chickens (Debut *et al*, 2005). Anecdotally, broiler chickens are typically shackled close together to prevent wing flapping at the point of shackling. Geese may bite nearby personnel or neighbouring shackled birds. Some bird types, and particularly those that tend to be active on a shackle line, may benefit from being adequately spaced out (eg if the shackle pitch cannot be spaced further then there should be an appropriate number of unoccupied shackles in between occupied shackles). This may limit opportunities for physical aggression as well as prevent struggling birds from beating their wings against other individuals, hopefully reducing transmission of disturbance. The most common shackle pitch for broiler chickens has typically been a 15 cm gap between birds (Kettlewell & Hallworth, 1990). Liao *et al* (2009) showed that increasing the shackling interval from 15.2 cm to 30.5 cm almost halved the proportion of red wing tips in ducks. If certain types of birds cannot be shackled without causing distress and/or high levels of continuous activity, then alternative methods of restraint and stunning may be necessary (Debut *et al*, 2005).

A breast support conveyor can be constructed underneath, and advance in time with, a standard shackle line (Figure 4). The conveyor supports some of the weight of the birds, thereby removing some of the pressure on their legs in the shackles. A conveyor may also keep the birds relatively upright. Compared with a conventional shackle line, this may result in reduced struggling at hang-on, more efficient entries to the electrified water and a lower incidence of wing damage (free-range broiler chickens: Lines *et al*, 2011). It is critical that the shackle line is straight because birds traversing corners on a conveyor may display increased disturbance and struggling, compared to birds on a conventional shackle line. Whilst a breast support conveyor may be advantageous for all types of birds, it may be particularly useful for heavy birds.



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Figure 4. Broiler chickens and turkeys atop a breast support conveyor. The conveyor advances at the same speed as the shackle line. Once each bird is shackled and sitting appropriately upon the conveyor, the shackler should fold the birds' wings into the natural closed position, to reduce the risk of pre-stun shocks.

Industrial experience of such conveyors suggests the principle can be used for large turkeys, but this has not yet been scientifically assessed. Even when using a breast support conveyor, shacklers are likely to be easily fatigued by shackling large birds so shacklers must be regularly rested to ensure they are physically and mentally able to afford the birds the necessary gentle care during handling.

Conveyors must be constructed of suitable plastic which will not trap birds' feathers, skin or other body parts. When breast support conveyors are used, operators must monitor birds and, when necessary, adjust the system or reposition individual birds. For example, the speed of a conveyor must be adjustable so it can match the speed of the shackle line. The height of a conveyor must be adjustable so the distance between the conveyor and the shackles allows birds to lie in comfortable positions. Operators must immediately tend to any birds that adopt awkward postures that lead to struggling or discomfort. Any healthy birds which are gasping or gulping in an unusual, strained manner must be assessed to determine why – they may be lying too far forward on their chest and require repositioning. The use of breast support conveyors, and supporting research, are in their infancy. Therefore installation of such devices must be carefully considered and continuously monitored to ensure welfare is not impaired in any way and that birds cannot escape the shackles.



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How to monitor a shackling team's ability to protect animal welfare

- A bird's activity should be observed during and immediately after a shackler has shackled the bird.
- A longer duration and a greater intensity of bird activity (eg flapping, struggling), and a greater proportion of birds displaying such activity, may be associated with certain individual shacklers. The reasons for the greater amount of bird activity may be revealed through a comparative observation of all shacklers' behaviour (eg are some applying more force during shackling?). Regular observation may allow identification of personnel who might require re-training.
- Birds can also be assessed for intermittent bouts of activity along a shackle line, up to the point of entry to the waterbath.
- Observers should take into account each shackler's position along a shackle line. They should observe each shackler in different positions along the shackle line, to determine if features of the shackle line directly affect bird activity or if they affect the ability of the operators to effectively and humanely shackle birds.
- A system that allows AWOs to trace an individual bird back to the specific person who shackled the bird, can allow for individual shacklers to be praised for their skill in shackling birds without causing them injuries and can also allow for identification of shacklers who may require re-training to reduce the amount of damage they may be causing to birds and to the meat. Coloured, ordered bands attached to a clearly visible part of each shackle is one method of identification.
- A CCTV system can allow AWOs and abattoir managers to periodically review slaughter personnel practices without disturbing the personnel.

Pre-stun shocks at the entrance to a waterbath

A bird's head must *always* be the first part of its body to enter the electrified water. Any possibility for a part of a bird to come into contact with electrified water *before the head is immersed*, may result in a severely painful electric shock (EFSA, 2004). It has been estimated that it takes approximately 100 - 150 milliseconds (ms) for an animal to perceive the application of a potentially painful stimulus (eg electric shock) to its body (Wotton, 1996). This means a bird's head must be submerged within the electrified water within approximately 100 ms of the first electrical contact (Wotton & Wilkins, 2004). Otherwise, the bird may experience a painful pre-stun electric shock.

Birds might be suffering from pre-stun shocks if, at the same point(s) on a shackle line, birds tend to suddenly exhibit abrupt behaviours that might indicate distress, eg flapping and/or high-pitch vocalisations. Also, if birds display more than one contraction on entry to the water, this may indicate interrupted application of the initial current flow.

Pre-stun shocks typically trigger an escape response in birds and therefore can cause them to flap vigorously (Kettlewell & Hallworth, 1990) and to lift up their heads, and sometimes their bodies, above the surface of the electrified water (Rao *et al*, 2013). As a result, birds may not be stunned immediately and may not receive an electric current for the minimum recommended duration; or they may not be stunned at all if



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they pass through the waterbath without making contact with the electrified water. Vigorous flapping may increase the likelihood of additional pre-stun shocks to the wings and the situation can therefore be cyclical. If neighbouring birds are hit by flapping wings they may be disturbed and begin flapping too (Kettlewell & Hallworth, 1990). Flapping birds may damage themselves, particularly if, in the panic, they beat their wings and hit their heads against the side panels of a waterbath. As well as being detrimental to bird welfare, pre-stun shocks are associated with damage to the carcass, eg red wing tips; haemorrhages in the wing, major fillets (dorsal and ventral aspects) and minor fillets (dorsal aspect); and broken pectoral bones (Wotton & Wilkins, 2004; Rao *et al*, 2013).

Risk factors for pre-stun shocks:

- A bird's wings are prone to receiving pre-stun shocks, particularly when the bird holds them open. In this position the carpometacarpus may be especially close to the water.
- The large wingspan of geese and turkeys puts them at particular risk of pre-stun shocks because their wings often hang below their head (EFSA, 2004).
- Agitated, struggling birds may hold their wings open and some flap; as such the wings may be more likely to make contact with the electrified water.
- EFSA (2004) stated: "...physical contact between birds on the shackle line make it difficult to control the current pathway and eliminate [the] potential problem [of pre-stun shocks]...". This risk may be greatest in birds with wet plumage (N. Gregory personal communication 2014). It is therefore preferable to leave a gap between each bird.
- Sometimes birds' legs and/or feet contact the earthed rubbing bar (eg when a shackle line descends just before the entrance to a waterbath). If the entry ramp is not electrically isolated or if electrified water overflows the entrance, such birds may receive pre-stun shocks (Bilgili, 1992). Aim for a 3 – 4 cm gap between the water surface and the brim of the entrance to the waterbath (Schütt-Abraham *et al*, 1983); the entry ramp may be higher than this.
- Pre-stun shocks may occur if a shackle line descends too gradually, as birds enter a waterbath (EFSA, 2004). For example, when a bird's beak touches the water current will begin to flow and the skeletal muscle in the body will contract, causing the bird to become rigid and typically arch its back (reflex dorsiflexion: Kettlewell & Hallworth, 1990). This rigidity may effectively lift up the bird, including its head. If, within one second of the initial contact, the beak momentarily loses contact with the water, the bird may receive a pre-stun shock. Thereafter, even if the bird's head regains contact with the water and becomes fully submerged, the earlier pre-stun shock may still have caused suffering.

If pre-stun shocks are suspected to occur, personnel must notify the AWO and/or veterinarian and there must be an investigation to identify the extent of the problem and the necessary corrective action, which may require redesigning the entrance to the waterbath, or perhaps the entire shackle line. If their sampling rate is fast enough, stun monitors (read the section '**Monitoring stunning parameters**') might be capable of recording pre-stun shocks (Figure 28b) and can therefore be used as a detection tool.



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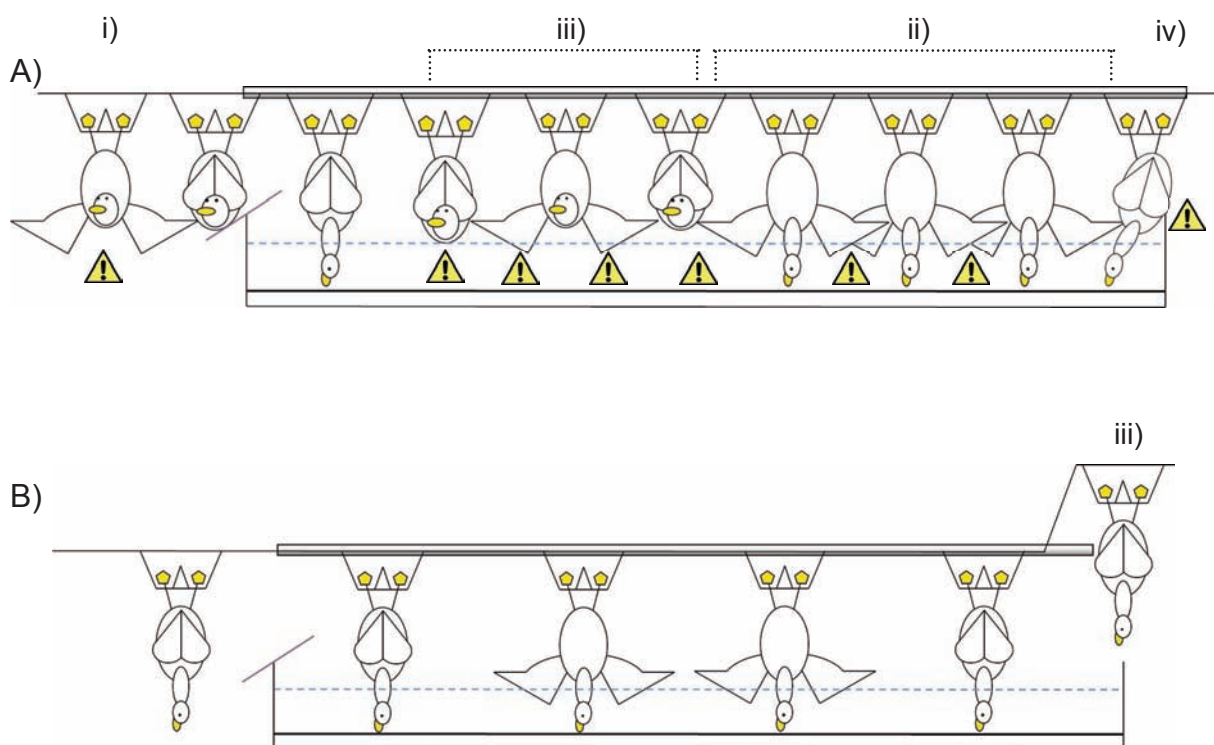
Figure 5. Arrangement of birds within a waterbath and the potential effects on welfare.

Arrangement A) may pose risks to bird welfare (indicated with warning triangles) because:

- i) the birds are shackled close together, which may cause flapping individuals to hit other birds with their wings;
- ii) the close proximity may also lead to birds physically touching one another, particularly if they hold their wings open; this may form alternative, lateral current pathways between birds;
- iii) some birds are swan-necking (curling their neck and raising their head) and either receiving pre-stun shocks to their wings or avoiding the electrified water entirely; one bird's chest is in contact with the water but its head is not submerged; this may lead to **electroimmobilisation** (conscious paralysis);
- iv) the bird exiting the waterbath is touching the end panel, which may cause a current 'spike' (Figure 23) which risks damage to the carcass.

Arrangement B) may be more conducive to bird welfare because:

- i) the majority of birds have closed wings, potentially reducing the risk of pre-stun shocks and bird-bird contact. Even the two birds holding their wings open and downwards, are adequately spaced apart to prevent physical contact between each other;
- ii) the birds hold their necks and heads vertically;
- iii) the bird exiting the waterbath is lifted up and over the panel by the shackle line, preventing repeat applications of current.





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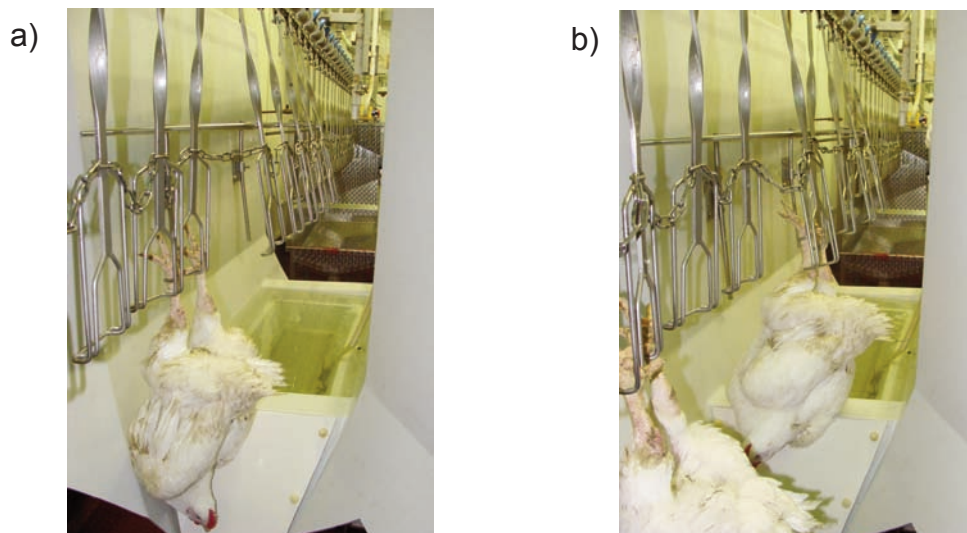
Actions that may minimise the risk of birds experiencing pre-stun shocks

To prevent pre-stun shocks, current flow to/through a bird must only be possible when the shackle is in contact with the earthed rubbing bar and, simultaneously, the bird's head is in full contact with the electrified water in the waterbath.

Kettlewell and Hallworth (1990) suggested that male and female broiler chickens should be processed separately because their differing body lengths make it difficult to set an optimum height for a waterbath and ensure all birds' heads immediately enter the water without pre-stun shocks. It was shown that, after experiencing a pre-stun shock, compared to males, a higher proportion of female broilers attempted to take flight (Rao *et al*, 2013); the authors suggested that, when inverted and shackled, the heavier males may be physically less able to move and escape further pre-stun shocks and "*are less able to avoid a swift immersion in the water-bath*". Abattoirs must attempt to prevent all pre-stun shocks in all sexes and may wish to consider slaughtering each sex separately. This is already done in sexually dimorphic species or types (eg ex-breeding birds of various species, broiler turkeys or Muscovy ducks; the males tend to be markedly larger than females). Consideration should perhaps also be given to other species or bird types, where less obvious variation in body length or weight may still affect the quality of entry to a waterbath. (The point at which such sexes might be separated is a difficult decision. Companies must consider whether sorting can be successfully and reliably carried out at the point of capture for slaughter, or whether it must take place earlier (eg sexing day-old chicks at the hatchery or sorting older birds on-farm prior to the date of capture for slaughter). Sexing and sorting may add another step to the sequence of potentially stressful events for the birds. Nevertheless, the concern for accurately delivering an effective electrical stun to both sexes remains.)

Anecdotally, some birds that do not flap may fold their wings into the closed position (Figure 5; Figure 6a,b) and hold them against the sides of their body, naturally keeping the wings away from the electrified water and also avoiding contact with neighbouring birds. Such a bird may also hold its neck and head down in a vertical line, which may

Figure 6a. A broiler chicken approaching a waterbath stunner. 6b. As the bird makes contact with the entry ramp its body is held back, facilitating thereafter a swift swing into the electrified water. The bird's wings are closed, reducing the risk of pre-stun shocks.





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allow the head to enter the water smoothly. Personnel should strive to ensure handling and shackling is of the highest quality because it may encourage this behaviour in birds.

If a waterbath accommodates only one bird at a time, passive body heat detectors (eg infrared) can switch on current flow only once the bird's head is over, or makes contact with, the water in the bath (Wotton & Gregory, 1991a). The timing of the detector must be extremely rapid and accurate to ensure a bird's head is not immersed without current flow. A gain control will allow adjustment of the sensitivity of the detector, depending on the distance of the birds from it. (Single-bird waterbaths are not common in commercial abattoirs.)

A steeply-inclined, smooth ramp ascending over the entrance to the waterbath (Figure 7a,b) may reduce the number of birds experiencing pre-stun shocks (Wotton & Wilkins, 2004). An entry ramp should begin below the level of the birds' wings, to prevent wings from becoming caught on the edge of the ramp (Wotton & Gregory, 1991a). A ramp should extend over the water a short distance and must briefly hold birds back at the top of the ramp (Figure 6a,b), so they gently, but rapidly, swing off the edge and their heads swing straight into the water in one smooth motion. The height and angle of a ramp must be adjustable so it can suit the shackle line and the size of bird being processed. Some ramps have sections cut-out of them to enable a bird's head to fall into the electrified water whilst holding back the bird's wings, preventing pre-stun shocks (Figure 7b).

Care must be taken to ensure birds do not receive pre-stun shocks from the entry ramp itself, by electrically isolating the ramp from the rest of the waterbath. This can be achieved by ensuring there is no physical contact between the ramp and the waterbath and by ensuring the ramp does not have a flow of [electrically 'live'] water running onto it from the waterbath (Wotton & Wilkins, 2004). The ramp can be electrically isolated by using a non-conductive plastic overlay with non-conductive bolts and insulating spacer washers between it and the original ramp (Figure 8) (Wotton & Gregory, 1991a). The birds, atop the overlay, should therefore not come into contact with the original ramp nor any water flowing down it.

A series of non-conductive rods (eg made of PVC) can be arranged in parallel to create a ramp (Figure 9a,b). The rods provide a surface for birds to travel along and act as an insulative overlay above the original entry ramp, thereby minimising the risk of contact with any water overflowing from the waterbath. Any water that does splash onto the spherical rods should flow down between and underneath the rods, away from the birds. The gaps between the rods must be kept clean of debris to ensure water can flow away from the birds.

On a horizontal shackle line only (not a dipped shackle line), a breast contact strip can be modified to perform two tasks: firstly it can act as a vertical breast contact strip whilst the birds are conveyed along the shackle line and then the part of the contact strip nearest the waterbath can be twisted into a horizontal position to form an entry ramp which the birds swing off and into the electrified water (Figure 10: Wotton & Wilkins, 2004). Once such an entry ramp has been mounted in its final and most appropriate position for minimising pre-stun shocks, it can be fixed to the waterbath to enable both devices to be adjusted together, eg raising or lowering the height. Wotton & Wilkins (2004) advise that an open-sided waterbath (Figure 12) may be necessary if using this type of entry ramp.



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Figure 7a. Use of an angled entry ramp to reduce pre-stun shocks

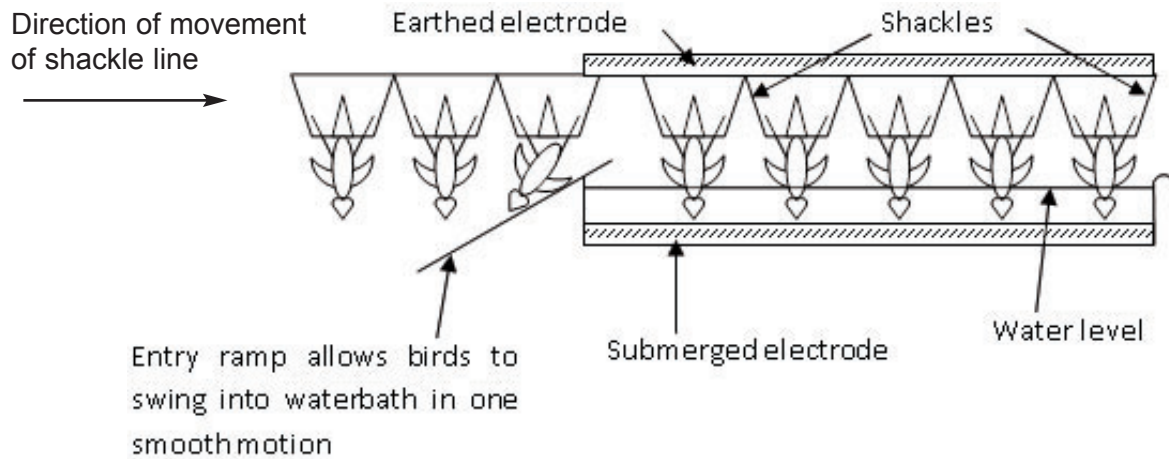


Figure 7b. An alternative design of entry ramp, where the edge has a section cut-away which causes a bird's head to drop through the opening, into the water, before the body and wings. Such ramps may need to be made-to-measure, to cater for the bird type being processed. The arrows indicate the direction of bird conveyance. Image on left: HSA (2006). Image on right: Marel Stork Poultry Processing.





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Figure 8. Addition of a sheet plastic overlay on an entry ramp

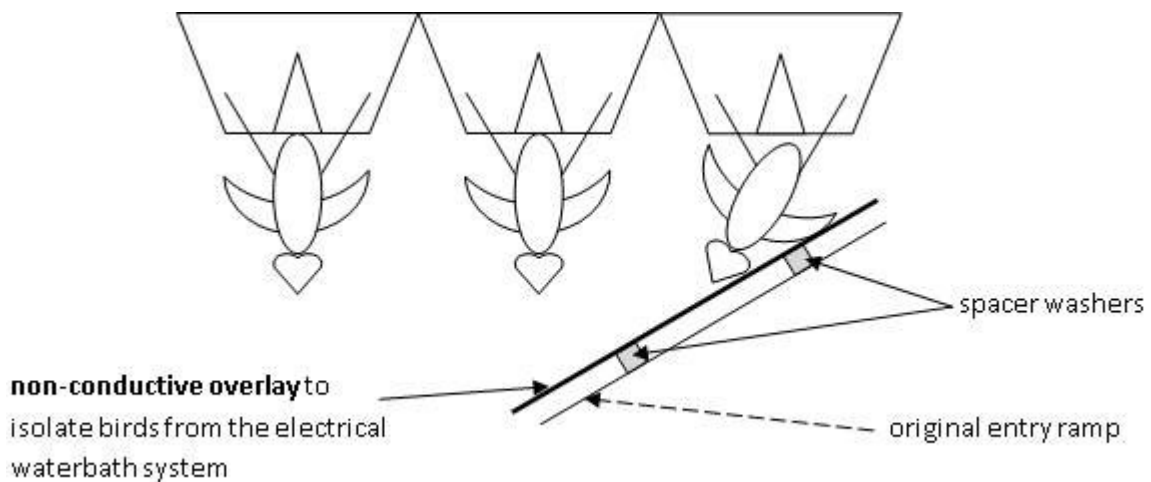


Figure 9a. Addition of plastic rods to act as an overlay on an entry ramp

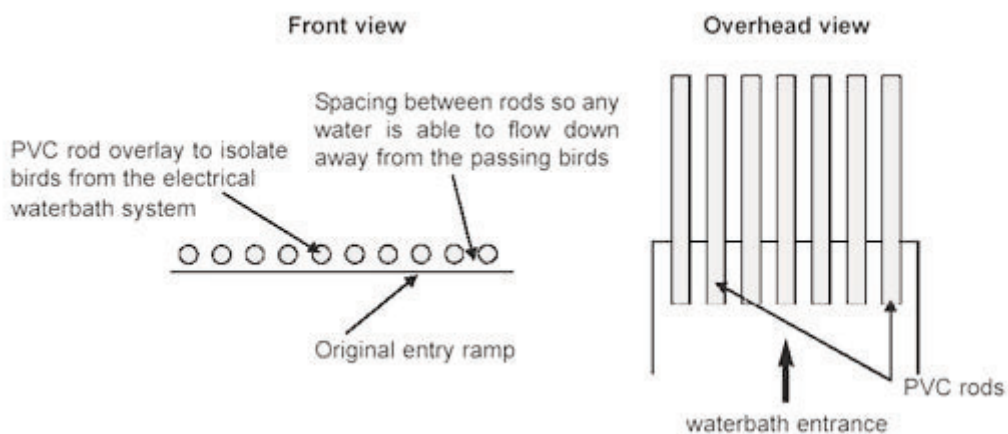


Figure 9b. Plastic rod overlay atop an entry ramp.

The rods should be kept clean of debris (eg feathers), to ensure water can quickly flow away from the birds atop the ramp.

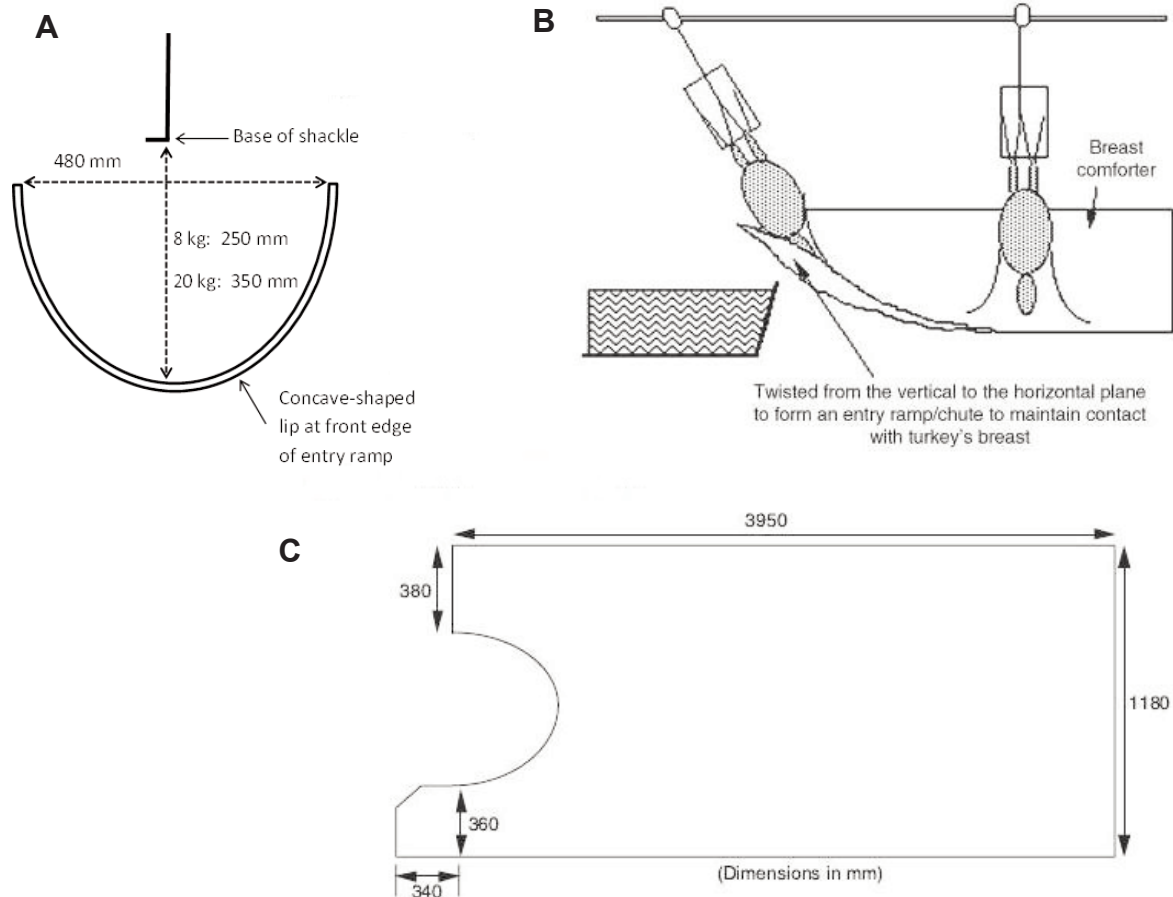
Image: Paul Berry Technical Ltd.





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Figure 10. A vertical breast contact strip designed and built to twist into an entry ramp at the entrance to a waterbath. The dimensions are suitable for turkeys of 8 - 20 kg liveweight but the design can be scaled-down for broiler chickens. **A:** a frontal plane view of the front edge of the entry ramp and a shackle. **B:** shackled birds against the contact strip and on the ramp. **C:** dimensions of the contact strip/entry ramp prior to twisting into position. Image A: HSA. Images B & C: adapted from Wotton & Wilkins, 2004, CAB International, UK.



Birds must be monitored as they move over an entry ramp. For example:

- If a shackle line descends as it passes over a ramp, then a large, heavy bird's head and neck can become trapped between its body and the ramp, whilst the leading wing dips into the electrified water. For this reason, ideally, a shackle line should remain horizontal (or should not descend too much) at the entrance to a waterbath, to enable the entry ramp to work.
- Whilst the legs continue advancing at the pre-set speed of the shackle line, when the birds' bodies contact the ramp their movement over it typically slows and their bodies, necks or shackles may overlap. Birds must be monitored to ensure they are not vigorously struggling, smothering one another, or that toes or feet do not become caught if the shackles cross over one another.
- As a bird enters a waterbath, its shackle must not overlap another shackle (whether occupied or unoccupied) because the bird's shackle will not be in direct contact with the earthed rubbing bar and may compromise the flow of current for each bird.



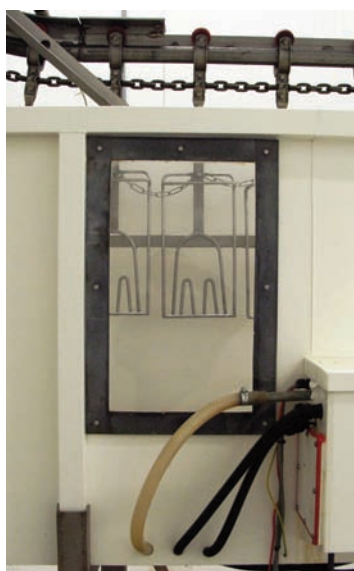
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- Small birds must not be shackled because they may fail to contact the entry ramp, not swing into the water and thereafter may continue to avoid the electrified water. Birds that are of an inappropriate size for effective stunning in a particular waterbath must be slaughtered using an alternative humane stunning method (eg the back-up device).

If operators try to perform animal welfare assessments in awkward, cramped conditions at the entrance to, or exit from, a waterbath, it can disturb conscious birds and even put the operator at risk of electrical injury or of being bitten or hit by a large flapping bird. Rather, installation of electrical waterbaths must be planned so all birds can be easily observed entering, passing through and exiting the waterbath, in order to frequently and properly assess the efficacy of the system. This can be achieved by installing large, transparent plastic windows (Figure 11) or a viewing platform above the waterbath. Alternatively, a waterbath constructed entirely of transparent plastic may allow safer monitoring of the entire system from ground level and at a distance that avoids disturbing conscious birds. (An opaque curtain can be used to screen-off the windows/waterbath when it is not being inspected.) If transparent waterbaths or windows are installed, they must be kept clean to allow accurate monitoring. Another alternative is an open-sided waterbath (Figure 12) (Wotton & Wilkins, 2004). These designs allow personnel to monitor birds' entries to the electrified water (to determine the incidence of pre-stun shocks) and the degree of immersion of the birds (to check their heads are submerged).

Systems that do not permit observation of birds entering or passing through a stunner can make assessment of effective stunning almost impossible, despite the fact the animals might be dead when they emerge from the system.

Figure 11. Viewing windows in the side panels of a waterbath stunner. The windows allow animal welfare to be monitored when the birds enter the water and as they pass through the waterbath.





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Figure 12. An open-sided waterbath stunner. The wide design of this waterbath prevents birds from flapping against, or becoming stuck against, the side panels and enables operators to monitor whether birds are immediately stunned and the depth of immersion of their heads in the electrified water throughout the entire length of the waterbath. For health and safety, an open-sided waterbath can be surrounded by a wire mesh cage to prevent any unauthorised access and thereby reduce the risk of accidental electrocution of personnel.

Image: PWO training, University of Bristol



SUMMARY: reducing the incidence of wing flapping in conscious birds on a shackle line and reducing the occurrence of pre-stun shocks

- Construct a straight shackle line from the first shackling point to the waterbath.
- Avoid constructing bends and inclines in a shackle line.
- Minimise the length of a shackle line to: a) avoid a need to increase the line speed, in order to reduce the time that conscious birds are suspended; b) reduce the number of conscious birds requiring attention during a line breakdown (Wotton & Wilkins, 2004; Defra, 2007).
- Unload, retrieve escapees and shackle birds calmly, gently and quietly.
- Shackle birds in correctly-fitting and appropriately-shaped shackles; if shackles are too tight they may cause pressure/pain which may provoke wing flapping.
- Replace any damaged or heavily-scaled shackles.



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- Use appropriate line speeds to prevent swinging of birds.
- Ensure the line moves smoothly without jolting/jerking.
- Maintain a low light intensity, or use low-intensity blue lighting.
- Avoid passing the shackle line through areas of sudden bright light.
- Prevent temporary loss of visual contact between neighbouring birds.
- Minimise ambient noise (including the rattling of shackles).
- Prevent sudden and excessive movement of air (wind tunnel effect - draughts may disturb birds).
- Ensure shackles and the earthed rubbing bar do not trap and pinch birds' toes or interdigital webbing since this may be painful and cause flapping.
- Use equipment that touches the birds' breasts, eg a breast contact strip or a breast support conveyor. Ensure breast contact is constantly maintained from the start of shackling through to the stunner.
- An entry ramp must be designed and positioned to allow a gentle but rapid flick of a bird's head into the water. Entry ramps also keep wings above the waterline and assist in preventing pre-stun shocks.
- Prevent any overflow of water from the entrance to the stunner; set up a drainage system at the exit of the waterbath.
- If electrified water does overflow from the entrance, install a non-conductive overlay atop the entry ramp, to electrically isolate the entry ramp.
- Ensure the water level in a waterbath is set according to flock size, to allow immediate submersion of the head of the smallest bird.
- A shackle line that descends at the entrance to a waterbath is a traditional design that lowers birds' heads into the water. These dipping lines are typically only suitable at fast line speeds (otherwise the slow entry into the water gives conscious birds an opportunity to resist immersion). Large birds like turkeys and geese may also be at greater risk of pre-stun shocks to their wings on slow-moving dipped shackle lines (Wotton & Wilkins, 2004).
- Ideally a shackle line should not descend at the entrance to a waterbath, when used in conjunction with an entry ramp.



Operating an electrical waterbath

Electricity

In order to choose the correct electrical parameters to achieve effective electrical stunning, it is helpful to understand the basic principles of electricity.

Voltage, current and resistance

Ohm's Law defines the relationship between voltage, **resistance** and current. Assuming a predominantly resistive system with negligible reactance, Ohm's law states that the current is directly proportional to the applied voltage and inversely proportional to the resistance of the circuit.

$$\text{Ohm's Law:} \quad \text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

To increase the amount of current flowing through a circuit, the voltage must be increased, or the resistance decreased.

Voltage is the electromotive force (emf) or electrical pressure that forces the flow of current and is measured in **Volts (V)**. Voltage may also be referred to as the electric potential difference between electrodes. It is necessary to maintain a voltage that is sufficient to produce a current strong enough to ensure that every bird is stunned.

Current (I) is the rate of flow of electric charge through a conductive object and is measured in **Amperes (A)**. The current is the most important parameter in terms of ensuring effective stunning; hence why recommended electrical parameters focus on the current and not the voltage. For example, voltage may vary across different circuits with the same current.

Electrical resistance (R) is a measure of an object's capacity to impede the flow of current and is measured in **Ohms (Ω)**. Resistance may also be described as **impedance**, particularly when referring to an object's resistance to alternating currents. The overall resistance of an object depends on several properties including the length, cross-sectional area and the resistivity of the material that forms the object. The resistance of an object is proportional to its length and inversely proportional to its cross-sectional area (Bilgili, 1992). Different materials have different resistances; metals are strong electrical **conductors** with a low resistance, whereas ceramics, plastics or glass do not conduct electricity well and therefore have a high resistance and are classed as **insulators**. Whilst it is possible to manufacture the electrodes and the shackles from materials with a relatively high conductance and low resistance, it is not possible to drastically alter the biological resistivity of the birds, although the resistance of living tissue can be reduced by increasing the voltage applied (Wotton & O'Callaghan, 2002). An animal is formed of various tissues including skin, muscle and bone which vary in their resistance to electricity (Woolley *et al*, 1986a). The arrangement of these tissues in the body ultimately determines the path along which the current flows. With time, a voltage progressively overcomes (to a degree) the resistance of the tissue(s) it is passing through, providing a higher current to the tissue (Wotton & O'Callaghan, 2002). However, electricity is likely to flow along the path of least resistance within an object. Therefore, an applied current is more likely to travel through the lower-resistivity tissues of skeletal (breast) muscle and cardiac muscle than through the more resistive skull bone (Bilgili, 1992). It is possible that the brain may only receive a very small proportion of the total current applied to the body, but



Operating an electrical waterbath

this may depend on whether a bird's eye(s) are in physical contact with the electrified water (ie submerged) or the electrified wet plate (read the section '**Maintaining an uninterrupted electrical circuit and optimising current flow**'). A bird's eye(s) may potentially provide a relatively low-resistance route (via the optic nerve) for an electric current to enter the brain. Otherwise, Woolley *et al* (1986b) estimated an average of 18% (range: 10 - 28%) of a current might enter an egg-laying chicken's brain via the skull bone. Therefore, it is absolutely critical that the minimum recommended currents are delivered, to increase the likelihood that enough current actually penetrates the skull, enters the brain and triggers unconsciousness.

Avian resistance

An individual bird's resistance is highly variable relative to other birds of the same type, as well as between strains, breeds and species (Table 2). Resistance may depend on factors such as age, size (but not necessarily live weight), sex, feather coverage, thickness of the skin and leg scales (degree of **keratinization**) (Bilgili, 1992), whether an animal's skin and/or plumage is wet, muscle and fat composition of the torso, an animal's state of hydration (Diez de Medina *et al*, 1993) and the thickness and density of the skull and tarsometatarsal (shank) bones. For example, it was suggested that the greater amount of abdominal body fat, the lower moisture content of body tissues (Rawles *et al*, 1995a) and the thinner legs are the reason why female broiler chickens have a greater electrical resistance than males, despite being almost the same age and weighing less. Based on limited research (Diez de Medina *et al*, 1993; Prinz, 2009), it appears that, at a constant voltage, female broiler chickens may receive approximately 75% of the current amplitude that males do. Females therefore require higher voltages than males, in order to produce the same current amplitude necessary for effective stunning (Prinz *et al*, 2012). Similarly, the fat and moisture content of female turkeys and the diameter and surface properties of their legs was suggested as a reason why they have a greater resistance compared to male turkeys (Schütt-Abraham & Wormuth, 1988; Rawles *et al*, 1995b; Mouchonière *et al*, 1999). Since the resistance of birds can vary widely (Wotton & Gregory, 1991b), before the first-ever attempt to stun a batch of birds of a type the abattoir has not slaughtered before, the abattoir should estimate, using the assistance of an electrical expert, the voltage amplitude likely to be required by all their different types (including sexes) of birds, in each of their waterbath stunners. Thereafter, once stunning begins, the voltage can be adjusted based on the required total current. The electrical parameters for each bird type should then be recorded in the standard operating procedures (SOPs) and periodically reviewed and altered as necessary to ensure operators keep up-to-date with any changes in the anatomical composition and/or slaughter age of bird strains/breeds, which might correspondingly require an adjustment of the voltage to achieve the same current. Limited data suggests it is possible that application of higher voltages in general may reduce the magnitude of difference in the current amplitude received by different animals, eg by each sex (Rawles *et al*, 1995a).



Operating an electrical waterbath

Table 2. Electrical resistances of poultry reported in scientific literature*. SD = standard deviation of the mean. ♂ = male, ♀ = female. The resistances are based on a 50 Hz sine AC. (Resistances may vary unpredictably with waveform and frequency (Wilkins *et al*, 1999a) and tend to be greater at low amplitude voltages/currents (Rawles *et al*, 1995a,b).)

This table is a guide to the approximate resistances of poultry; because resistance varies with many factors, these values are not guaranteed; abattoirs must identify the resistances of the specific birds they slaughter. Nevertheless, the table allows the estimation, using Ohm's Law, of the voltage amplitude necessary to attain the legally-required or recommended currents. To ensure as many birds as possible are effectively stunned, the resistance at the upper end of the range should be used to estimate the voltage required per bird.

Note: mention of foie gras does not imply the HSA agrees with this practice; simply, information is provided because the physical attributes of such birds may affect resistance.

*Gregory & Wotton (1987), Schütt-Abraham & Wormuth (1988), Diez de Medina *et al* (1993), Sparrey *et al* (1993), Wilkins *et al* (1998), Mouchonière *et al* (1999), Fernandez *et al* (2003, 2010), Rémignon (2004), Rodenburg *et al* (2005), Hindle *et al* (2009), Prinz (2009).

Bird type	Average resistance Ω (SD)	Range of resistance Ω	Live weight kg Average (range)
Broiler chicken	1000 - 1600 Ω (200 - 600) ♂: 900 ⁺ ♀: 1200 ⁺	800 - 3900	2.5 kg (1.7 - 3.5)
Egg-laying chicken	2500 - 2900 Ω (500 - 800)	800 - 7000	1.9 kg (1.3 - 2.4)
Turkey	2100 - 2300 Ω	Up to 5700	5 - 10 kg
	1200 - 1600 Ω		8 - 25 kg
Guinea fowl	2900 (1400) Ω		1.2 - 2.3 kg
Duck	1600 - 1800 Ω (300 - 400)	900 - 2800	2 - 3.8 kg
Male mule (Pekin x Barbary/Muscovy)	2600 (420) Ω	2100 - 3300	4.2 kg (6.5 kg for foie gras)
Goose	1900 (500) Ω	Up to 4100	4.3 - 6.7 kg
French Landes for foie gras	2700 Ω		possibly 8.5 kg



Operating an electrical waterbath

Waveform

The waveform describes the shape of one cycle of the voltage or current. Current can be generated as an alternating current (AC), where the direction of the current flow alternates around zero with positive *and* negative direction (bipolar; Figure 13a,c,e,f). Alternatively, a direct current (DC) flows in only one direction (unipolar), either the positive or the negative (Figure 13b,d). DC currents are typically pulsed (pDC), meaning the current is turned off (zero amplitude) for a proportion of the cycle time. The resulting waveform can be expressed by the mark:space ratio (where the mark is the time the current is 'on' and the space is the time the current is 'off', ie at zero). An alternative description of this is the **duty cycle**, where the duration of the mark is expressed as a percentage of the duration of the cycle time.

The way an AC or DC current flows can be examined over time to reveal the shape/form of the wave. For example, waves can be smooth undulating curves (**sinusoidal** or **sine**), square or rectangular, sawtooth or triangular. Current can also be modified to produce different waveforms. For example, AC waves can be rectified to different degrees (eg half or fully) to produce DC waves (eg pulsed or constant, respectively). Or a wave can be clipped to produce various different shapes. A variety of waveforms (including some of those shown in Figure 13) have been used in electrical waterbath stunners, mainly to attempt to reduce carcass damage or to improve the efficacy of the electrical pulse. However, so far, scientific research indicates that carcass quality is not necessarily improved when waveforms are altered and a sine AC appears to produce the most effective stuns for animal welfare (Hindle *et al*, 2009).

Frequency

The frequency of a current is the number of repetitions of one complete cycle of the waveform per second and it is measured in **hertz (Hz)**. For example, 'standard' mains electricity in Europe is characterised by a sinusoidal waveform with a frequency of 50 Hz, ie it repeats 50 times per second (Figure 14a). If there are 50 cycles every second, that means one full cycle is completed in 20 milliseconds; this duration is known as the **period** of the current. Waveforms that repeat one full cycle a greater number of times per second will have a higher frequency, eg the current in Figure 14b has a frequency four times greater than the current in Figure 14a.

Descriptive units of current and voltage

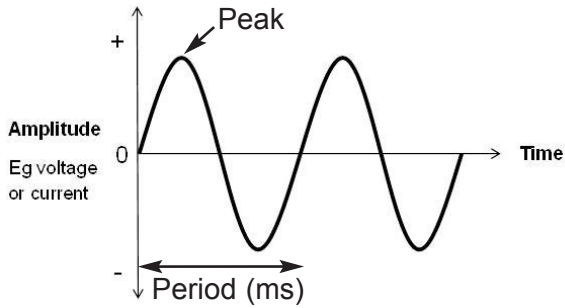
There are various ways of reporting the amount (amplitude or magnitude) of a current or voltage. For example, **peak** amplitude is the height of a wave from zero to either the highest positive point, or the lowest negative point. However, it is useful to report current amplitude as an *average*. At a 50% duty cycle (1:1 mark:space ratio) a pDC waveform will have an average current that is always half of the peak current. For different duty cycles, the average and peak current can be calculated (read '**peak current**' within the *Glossary*). For AC, if the proportion of time the wave spends above zero is equivalent to the time spent below zero, the mathematical average will be zero and meaningless. Instead, the '**root mean square**' (RMS), or 'effective', current can describe an AC wave. Abattoir personnel must always report the appropriate descriptive units when recording the electrical parameters used in a stunner (eg 'RMS' for AC, 'average' for pDC and the constant amplitude value for DC).



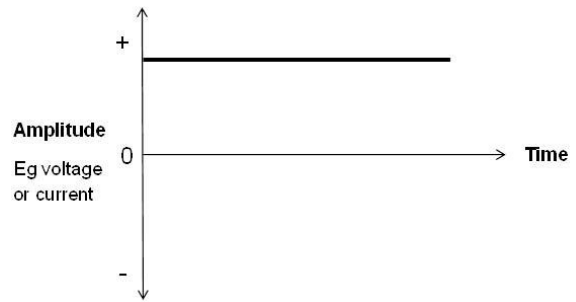
Operating an electrical waterbath

Figure 13. A selection of AC and DC waveforms. Time is typically described in milliseconds (ms). Rectangular and square waves are differentiated by their pulse widths. (Note: this figure is for descriptive purposes only, to enable understanding of electrical terminology; the waveforms shown are not necessarily appropriate for humane electrical stunning of animals.)

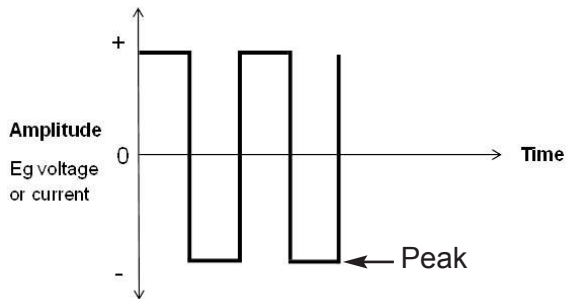
a) Sinusoidal (sine) AC 100% duty cycle (2 cycles shown)



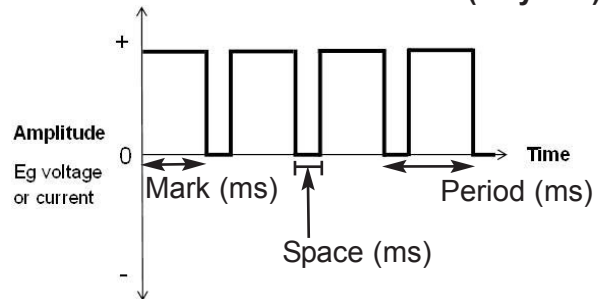
b) DC 100% duty cycle



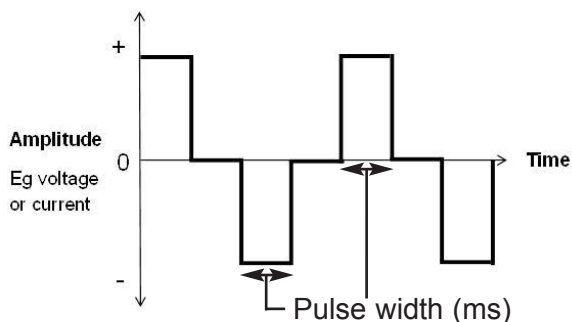
c) Rectangular AC 100% duty cycle (2 cycles)



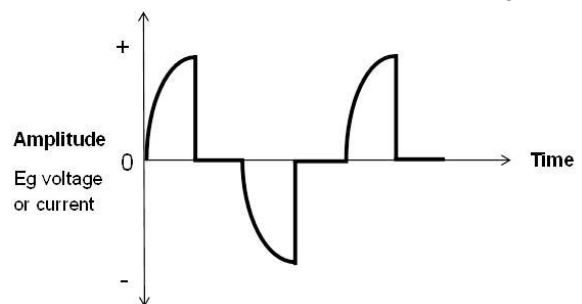
d) Pulsed rectangular DC 75% duty cycle or 3:1 mark:space ratio (4 cycles)



e) Pulsed rectangular AC 50% duty cycle (1.75 cycles)



f) Clipped sine AC 50% duty cycle (1.5 cycles)





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Figure 14a. A sinusoidal 50 Hz wave. 5 cycles in $1/10^{\text{th}}$ sec = 50 cycles per second

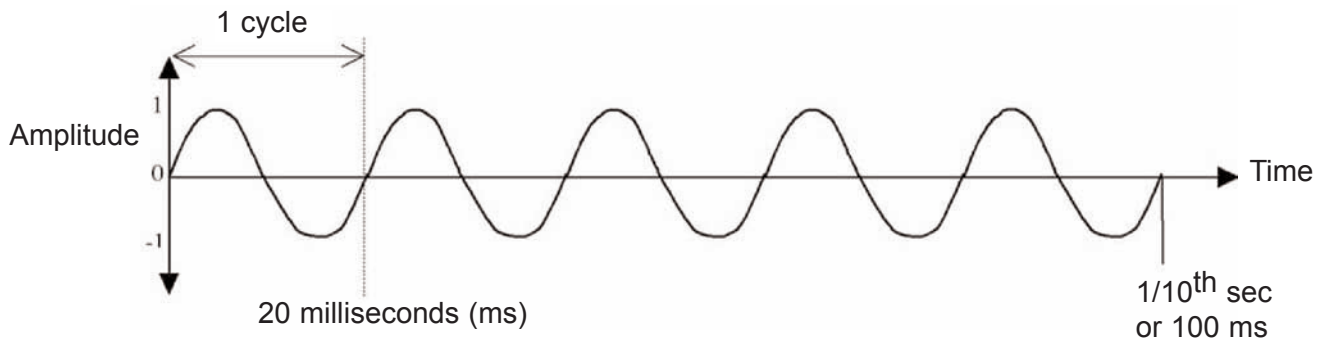
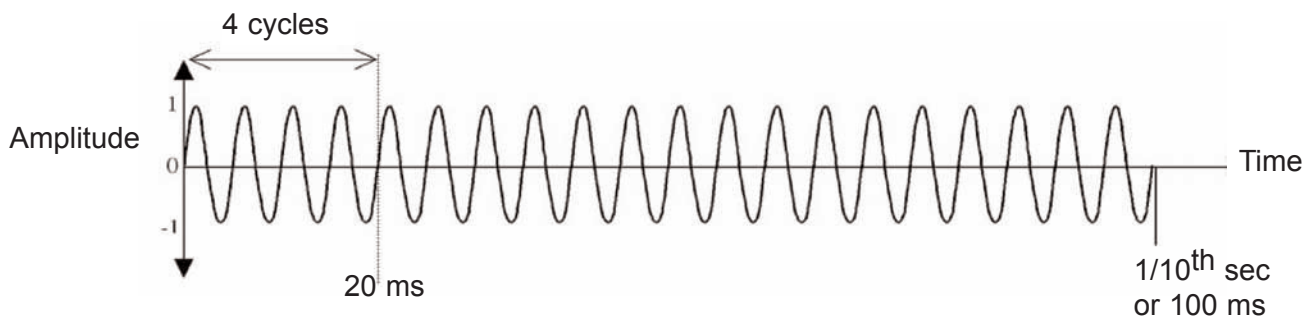


Figure 14b. A sinusoidal 200 Hz wave. 20 cycles in $1/10^{\text{th}}$ sec = 200 cycles per second



Summary of electrical terminology, with regard to the parameters that must be specified in SOPs for each stunner on-site (including for each phase of multi-phase stunners) and for each type of bird processed

- **Current (*I*)** = the flow of electricity through an object. Always specify the units used, eg mA RMS for AC; mA average for pDC; mA for DC.
- **Voltage (*V*)** = the driving force (electrical pressure). Always specify the units used, eg V RMS. (Remember: even if the required current amplitude is identical for different bird types (eg broiler and egg-laying chickens), the voltage required to achieve this current may differ between the bird types due to their different resistances.)
- **Waveform** = the shape of one complete cycle of electrical current. Must include the polarity (ie whether AC or DC) and the shape (eg sine, rectangular, the proportion of any clippings of the wave).
- **Frequency** = the number of complete cycles per second.
- **Period** = the amount of time taken to complete one cycle of the waveform.
- **Pulse width** = the amount of time for which the current flows (ie the 'on' time) within a single period.
- **Duty cycle** = the pulse width, expressed as a percentage of the period.



Operating an electrical waterbath

Constant voltage versus constant current

The commercial electrical waterbath systems presently in use, operate using a *constant voltage*. Constant voltage stunners are designed to apply an equal voltage to each bird passing through a waterbath, whether it accommodates a single bird or multiple birds. The resultant amplitude of current flowing through an individual bird within a constant voltage stunner may depend on:

- the voltage amplitude at which the system is operating
- the electrical resistance of the whole circuit (from the live, submerged electrode, to the water, through the bird and the shackle, to the earthed rubbing bar)
- in a multi-bird waterbath, the current amplitude each bird receives also depends on the total number of birds in contact with the electrified water at any one time (Wotton & Gregory, 1991b), which is typically up to 20 but can be as many as 40 individuals

Most constant voltage waterbath circuits operate with the resistors (birds) in parallel and each bird effectively acts as a separate branch of the circuit. The stunner should apply to each bird, the same voltage as shown on the voltmeter. Therefore the voltage required to overcome the resistance of a bird of that type can be estimated using Ohm's Law ($V = I \times R$), along with the resistances (R) provided in Table 2 and the recommended current amplitude (I) (eg provided in Table 4). For example, to deliver a current of 0.1 A (100 mA) to a bird with a resistance of 1500 Ω , will require 150 V. As a bird's resistance increases, so too will the required voltage to achieve the same current.

The minimum total current required for a waterbath will be the maximum number of birds that can simultaneously be in the water, multiplied by the minimum required current per bird (Schütt-Abraham & Wormuth, 1991), eg Figure 15A. However, this is, at best, an estimate because it assumes all birds have equal resistances, which, in reality, they do not.

When a pre-determined, constant voltage is applied to a group of birds, each bird's different level of resistance will cause it to receive an associated different current amplitude (Table 3; Figure 15B; Figure 27). This means a bird with a lower-than-average resistance may receive more current than the operator intends and therefore may be stunned (but may also experience more damage to the carcass); whilst a bird with a higher-than-average resistance might receive less current than the operator intends and may not be adequately stunned (Berry *et al*, 2002). Therefore, attempting to deliver to every bird, the minimum recommended current per bird, using a multi-bird constant voltage stunner, is extremely difficult, even though the voltage required must be manually determined in advance. In addition, the total resistance of an electrical system is unlikely to ever be constant, but may vary with changes in the resistance of the water, the birds (including the number of birds in the waterbath) and the leg-shackle-earth interface. The voltage required by the same system may vary from day-to-day (Hindle *et al*, 2009) so abattoirs must ensure the same total current is delivered to a stunner, not necessarily the same voltage. It is therefore important to keep the total resistance, and the variation in resistance, of each branch of a circuit as low as possible (through adequate cleaning and maintenance of shackles and stunning equipment), to maximise the amplitude of current flowing through each bird.



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Table 3. Examples of the possible outcome of using a constant voltage stunner to attempt to deliver the minimum required current to two different types of chicken. In example 1, the resultant current delivered to the end-of-lay hen, is below that permitted by EU law; the voltage amplitude must be increased to 500 V RMS in order to raise the current amplitude to 100 mA RMS and increase the likelihood of an effective stun. (When using electrical waterbath stunners, the leg-shackle interface accounts for the large variation in a circuit's resistance.)

Example 1:	Broiler chicken (thinner, softer skull; wide, soft-scaled shanks that fit closely in shackle)	End-of-lay chicken (thicker, harder, denser skull; thin shanks fit loosely in shackle; dry scales on shanks)
Voltage applied:	250 V RMS	250 V RMS
Electrical resistance of circuit, including bird:	2500 Ω	5000 Ω
Resulting current:	100 mA RMS	50 mA RMS
Outcome for bird welfare:	Effective stun	Ineffective stun (eg electroimmobilisation)
Example 2 (Wotton & Wilkins, 2004; AWTraining, 2008):		
Voltage applied:	160 V RMS	380 V RMS
Electrical resistance of circuit, including bird:	1600 Ω	3800 Ω
Resulting current:	100 mA RMS	100 mA RMS
Outcome for bird welfare:	Effective stun	Effective stun

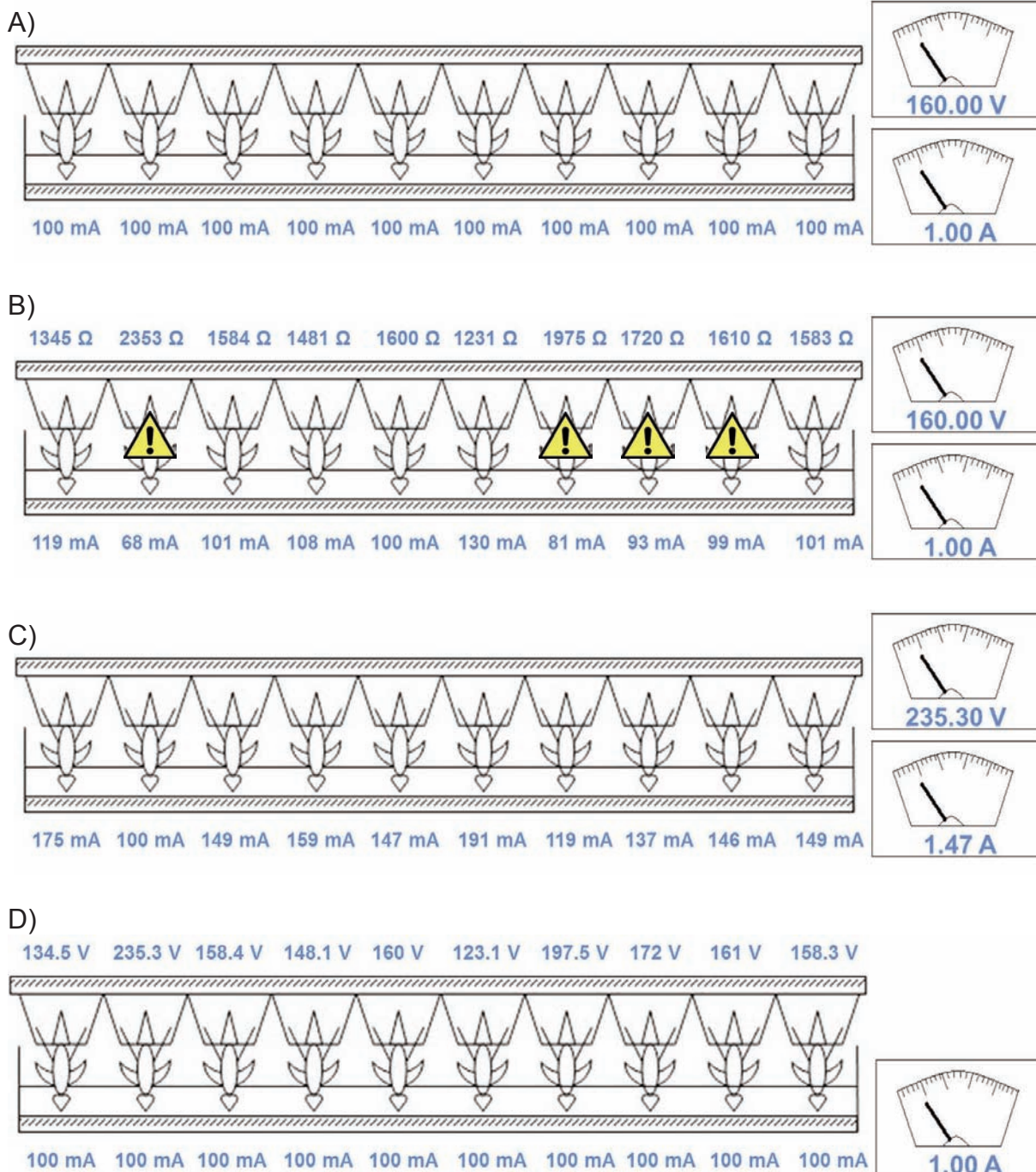
When using constant voltage equipment, try to achieve as consistent a current per bird as possible. To do this, operators must ensure:

- Constant voltage equipment must be capable of maintaining, as near as possible, a constant voltage, irrespective of the number of, or resistances of, birds in the stunner (Schütt-Abraham & Wormuth, 1991; Bilgili, 1992).
- The power output of the mains transformer circuit must be able to cope with the maximum load on the circuit (Kettlewell & Hallworth, 1990), based on the maximum possible shackle fill and the typical maximum resistance of the bird type being killed.
- Although the resistance of a circuit reduces, to a degree, with increased duration of current flow, it is critical that the equipment is capable of delivering high enough voltages to ensure resistance is broken down as quickly as possible (within the first period of current flow), to maximise the likelihood that birds are rendered immediately unconscious (Raj & O'Callaghan, 2004a). Otherwise, low voltage systems may take longer to reach the desired current amplitude (eg 2 – 4 seconds depending on the species: Schütt-Abraham & Wormuth (1991)), during which time the bird may not yet be rendered unconscious.



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Figure 15. Illustration of the current and voltage used to attempt to supply each bird with a prescribed current of 100 mA. A voltmeter and ammeter are displayed on the right and the parameters per bird are shown above and/or underneath each bird. A) If it is assumed that all birds have an average resistance of 1600 Ω . B) In reality, each bird may have a different resistance which causes them to each receive a different current amplitude in a constant voltage system. The warning triangles indicate birds that receive less than 100 mA and, as a result, may not be effectively stunned. C) To combat this animal welfare problem, the voltage of a constant voltage stunner should be increased to ensure all birds receive at least 100 mA. D) Alternatively, a constant current stunner can alter, as necessary, the voltage applied to each bird, in order to deliver the same prescribed current to each bird. (Note: all figures are examples; the voltages shown should not be assumed to be the necessary voltage to achieve these current amplitudes in practice because this may vary with systems. For guidance on appropriate parameters, read the section 'Parameters for stunning'.)





Operating an electrical waterbath

A more preferable electrical stunning system for animal welfare and meat quality will operate using a *constant current*. The challenge of the natural, multi-factorial variation in individual birds' resistance, and across the range of available electrical parameters, is met by automatic variation in the applied voltage, to ultimately produce a very similar current amplitude for each bird, ie sufficient current for bird welfare but not too much current for meat quality, eg Figure 15D. Unfortunately, whilst constant current systems have been used since the 1990s for scientific research (eg Sparrey *et al*, 1993; Rawles *et al*, 1995a,b), no large-scale commercial waterbath systems are yet available to industry.

Maintaining an uninterrupted electrical circuit and optimising current flow

A conventional electrical waterbath stunner allows current to flow between two electrodes, from the submerged electrode to the earthed rubbing bar. Electricity will only flow through a closed electrical circuit. Therefore, all electrical contacts within a circuit must be continuously, physically maintained, ie the bird's head with the electrode/electrified water, the bird's legs with the shackle and the shackle with the earthed rubbing bar. Even when all objects within an electrical circuit are physically connected, the flow of current between them can be compromised by the inherent characteristics and the quality of the electrical contact(s). If a waterbath has inadequate electrical contact, the problem cannot be solved by simply increasing the voltage supplied, because this may not necessarily improve stunning and may instead affect meat quality and increase the risk to human health and safety. It is possible to reduce the resistance of a circuit, at the points of electrical contact. Indeed, this is an essential basic procedure in the operation of any electrical system.

The live electrode-water-bird interface

A waterbath must be capable of precise vertical adjustment. A hydraulic lifting system may be required to quickly raise or lower a waterbath whilst it is filled with water (Wotton & Wilkins, 2004). If a large proportion of birds avoid the electrified water it is likely the waterbath height, and perhaps also the water level, need adjusting. The height of a waterbath and the depth of the water within it must be regularly monitored by abattoir personnel and be adjusted, as necessary, to allow full submersion of the head, including the eyes and cranium (the part of the skull encasing the brain), of all birds in the batch. Deep immersion of a bird's head requires less voltage to achieve a given current, compared to shallow immersion (Raj, 2004). In ducks, when only the beak and crop are immersed, disruption of normal brain function is typically less profound and this may be due to the brain receiving a lower proportion of the current that is passing through the whole bird (Gregory & Wotton, 1992a). Unfortunately it may be difficult to achieve complete submersion of the heads of waterfowl (the heads appear to involuntarily float at the water's surface). Therefore it may be important to install a device that submerges the cranium of each duck or goose, eg a neck extender - although these may have limited success (Figure 16b) (AWTraining, 2008).

Birds may be submerged up to the rostral edge of each wing (ie shoulder level: Figure 1), if this ensures immersion of the head of the smallest bird in the batch being processed (Schütt-Abraham *et al*, 1983; Gregory & Wotton, 1991b). In Europe, birds must be immersed up to the base of the wings (EC Regulation 1099/2009). However, care should be taken if birds are immersed deeper than the shoulders, because there may be a risk of current bypassing the head and brain and birds may not be rendered unconscious, although this is yet to be scientifically investigated.



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If a shackle line is moving at a fast speed with a large number of birds per minute, such that the water is pulled from the entrance of the waterbath towards the exit, causing birds' heads to not be fully submerged at the start of stunning, then the water level should be raised to counter this effect and ensure complete submersion of the heads for the entire length of the waterbath.

Wet plate electrical stunning systems

Some electrical, whole-body stunning systems for poultry do not operate with a deep 'bath' of electrified water. Instead, they may operate with a shallow bath of water and/or simply run water over a live electrode (hence 'wet plate'), with which the birds' heads make direct contact (typically the sides of their heads are dragged over the electrode as the shackle line advances). In most cases, the principles that apply to waterbaths also apply to wet plate systems, eg maintaining good electrical contact, including the ability to adjust the height of the stunner to ensure the birds' heads make full contact with the electrode. Wet plate systems have been found to offer inconsistent contact (Kuenzel & Ingling, 1977) and may put birds at risk of pre-stun shocks (Gregory & Whittington, 1992). Therefore if they are used, operators must ensure every bird's head makes full, continuous contact with the live electrode in the appropriate manner and before any other body part touches the electrode. Despite offering direct physical contact between a bird's head and the electrode, wet plate systems appear unable to overcome the aforementioned variation in resistance between sexes of broiler chickens (Prinz, 2009).

The purpose of electrical stunning is to induce epileptic activity in the brain, leading to neuronal fatigue (EFSA, 2004), which ensures a lack of consciousness. Therefore the equipment must always be organised so that current is physically directed through an animal's brain.

Electrodes must be placed so the target organ (brain) lies between them (EFSA, 2004). There must not be any opportunity for current to bypass the brain and travel instead through other (eg less resistive) body tissues. For example, if a bird's head remains above the electrified water or does not contact the electrified wet plate, but its chest is the first point of contact with the water or the plate electrode, then the chest will still complete the electrical circuit and current flow may be evident from the immediate cessation of movement in the bird and a rigid posture. However, it is possible the brain is not in the pathway of current flow and there is a significant risk the bird may experience **electroimmobilisation** and merely be **paralysed** whilst remaining conscious and capable of suffering extreme pain and distress. This is a possibility in all species, but is a particular risk for some species which have a tendency to swan-neck on a shackle line (Figure 16a). Despite this risk, it is possible for a bird's entry into electrified water to be swift and effective if an entry ramp is used; but flocks must be monitored to ensure this is the case. If it is not, neck extenders (Figure 16b) can also be used with long-necked species, to guide the heads completely under the electrified water almost immediately (EFSA, 2006), although

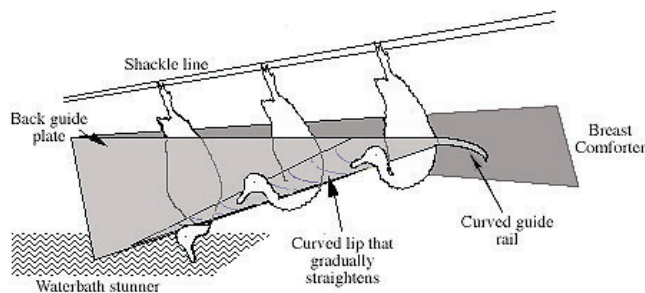


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Figure 16a. A swan-necking duck on a shackle line. Compared to the other ducks, with their necks and heads hanging down, the duck second from the right has curled its neck up so the chest is below the the head. If its chest makes contact with the electrified water before the head, there is a risk the duck may experience current flow without loss of consciousness because the brain is unlikely to be in the path of current flow. This will be inhumane.



Figure 16b. An example of how a neck-extender for ducks might work on a shackle line.



these may have limited success (AWTraining, 2008). The installation of neck extenders must be carefully planned so they do not obscure viewing for the assessment of the immediacy of stunning and the absence of pre-stun shocks. Once installed, neck extenders must be monitored to ensure all birds' heads are indeed pushed below the neck extender (and not trapped above it, which may cause pre-stun shocks to the wings or chest and electroimmobilisation).

To maximise the current amplitude received by the birds, the submerged electrode must always be as close as possible to the birds' brains, both horizontally and vertically (Figure 1). In terms of the horizontal, the submerged electrode must extend across the entire length and width of the bottom of the waterbath. Figure 17 illustrates what happens when an electrode does not span the entire length of a waterbath. In terms of the vertical distance, it is ideal if birds' heads touch the live electrode, as long as the heads are also simultaneously and completely submerged under the electrified water. As the distance increases between a bird's head and the submerged electrode, then even with a fully-submerged head, there may be a reduction in the amplitude of current received by the bird. For example, 265 V delivered 182 mA to a resistor in physical contact with a live electrode. When the resistor and the live electrode were moved apart by 5 cm and 20 cm, the current received by the resistor was 4 mA and 10 mA lower, respectively (Schütt-Abraham *et al*, 1991). Therefore the live electrode should always be as close as possible to, and preferably within 5 cm of, the beaks of the birds to ensure their whole heads are exposed to a sufficient current (Figure 1).

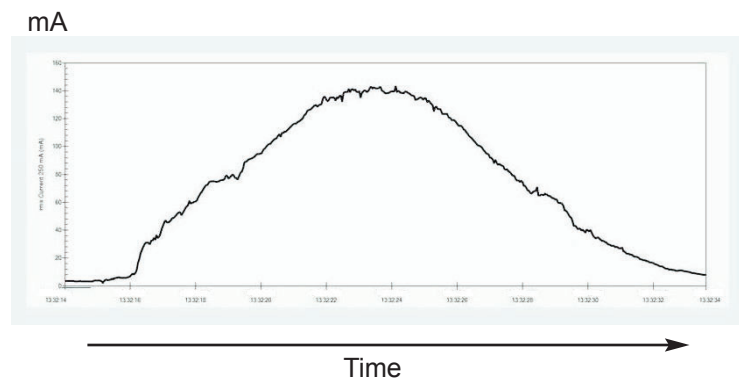


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Configuring a stunner in this manner may ensure the patency of the circuit for each bird and that they are all exposed to the minimum stunning current for the entire time they are submerged. If some of the birds' heads do not physically touch the submerged electrode, adding salt to the water may reduce the amount and variability of resistance between the birds and the water.

Figure 17. A current profile of a bird as it moves through a waterbath stunner. The current amplitude increases as the bird is conveyed towards a centrally-located submerged electrode, and decreases again as it passes the electrode and moves through the second half of the waterbath. A centrally-located electrode is not conducive for animal welfare because there is a delay in the time taken to reach the intended current amplitude. As a result, the stun may not occur immediately. This is why electrodes must span the entire length and width of a waterbath.

Image: Paul Berry Technical Ltd.



The **conductivity** of water may increase with the time a waterbath is in use because, as they pass through a waterbath, birds may void bodily fluids and dirt may be washed off their feathers, adding electrolytes to the water (EFSA, 2004). By comparison, the water in a waterbath may be relatively clean (and less conductive) at the beginning of a shift, or whenever it is replaced with fresh water during a shift. To create a more initially conductive fresh water, salt can be added to benefit both bird welfare and carcass quality (Perez-Palacios & Wotton, 2006), although this may be more important in geographical locations where the available water is of low conductivity. Less electrical force (voltage) is required to push a current through a bird when in a brine solution, than when in tap water (Bilgili, 1992). At concentrations of even 0.1% **weight/volume** (EFSA, 2004), food-grade salt can be added to the water and should dramatically increase conductivity. Although adding higher concentrations of salt may further reduce resistance, the effect is marginal beyond 1% and the voltage required is unlikely to decrease much further (Schütt-Abraham *et al*, 1991; Bilgili, 1992). So adding salt, even in large concentrations, may not improve a system that is inappropriately set-up, nor can it compensate for using a voltage that is insufficient to deliver a minimum recommended current per bird (eg Prinz, 2009). It is more important that a waterbath control panel is powerful enough to supply sufficient current to a waterbath, for the intended number of birds simultaneously in the water and for the water conductivity, without the stunner's circuit breaker 'tripping' (turning off) the circuit; that way, it will only be necessary to add salt as a last resort (P. Berry, pers. comm. 2014). Addition of salt to a waterbath should be considered an additional step that may further improve current flow in a system that is already providing the



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correct set-up and parameters. Salt is corrosive and over time the equipment will need to be cleaned, repaired or replaced to maintain efficient conductivity. Increasing water conductivity too much may increase the risk of pre-stun shocks (by allowing voltage to track further over the damp surfaces of the waterbath entrance) and may decrease the amount of current flowing through the birds during immersion (P. Berry pers. comm.). Also, disposal of brine effluent may have a detrimental effect on the environment and therefore salt should not be used excessively or needlessly (Schütt-Abraham *et al*, 1991).

Further, 20 – 30 minutes after adding salt to fresh water, the gain in conductivity may be lost (Perez-Palacios & Wotton, 2006). Therefore the current needs to be monitored closely during this time and, if necessary, the voltage should be increased to compensate for any decrease in conductivity and current (EUWeINet, 2013a). A decrease in conductivity may be particularly likely if clean water is frequently pumped into a waterbath (eg to top-up the water level). Digital conductivity meters are available to measure the electrical conductance of water, so AWOs can monitor how it changes with time and identify how often they need to add salt, depending on the rate of exchange, or loss, of water, from the waterbath. There must be an efficient system for adding salt to the water so that the conductivity of the water remains consistent (Bilgili, 1992). For example, after changing to fresh water and/or adding salt, before stunning resumes, it may be important to allow time for the salt to dissolve in the water and provide the greatest effect. If, to help achieve this, warm water is used, then the water temperature must not be increased above a level that would be comfortable for a conscious bird if one made contact with the water without being rendered unconscious (eg if it receives a pre-stun shock or if it escaped the shackles and is stood in the waterbath). Alternatively, a pre-mixed saline solution can be mixed into the waterbath water. (Note: raising the water temperature does not appear to have a significant effect on conductivity (Perez-Palacios & Wotton, 2006).) Unless the salinity of a waterbath can be continuously maintained, the addition of salt to the water should not be practiced (EUWeINet, 2013a).

In the interests of animal welfare and meat quality, try to limit the risk of the formation of current pathways between adjacent shackled birds. Such alternative electrical pathways may cause additional variation in the current each bird receives. For example, in a modelled system, Sparrey *et al* (1992) calculated that the average current varied by -46 to +39%. Therefore, birds should be shackled with sufficient space between one another so they do not touch (Figure 5B).

Birds must be able to pass through a waterbath without impacting against, or being hindered by, any obstacles (Schütt-Abraham & Wormuth, 1991). For example:

- Make sure the submerged electrode is not of a size or shape, or in a position, that obstructs birds' heads from swinging swiftly into the water, or from being fully submerged.
- The width of a waterbath must comfortably accommodate all the types of birds it is used for, so their heads cannot become trapped against the side panels (Figure 18), which can prevent the head from entering the water. To ensure as much room is available as possible, the shackle line should be located to one side of the waterbath (the side panel that is nearest to the birds' breasts). Alternatively, open-sided waterbaths can be used which also allow visual inspection of bird welfare (Wotton & Wilkins, 2004).



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- If any bird escapes from its shackle and is stood in the waterbath, then, depending on its position in the waterbath, it may prevent other shackled birds from being immediately stunned. The escaped bird may a) alter the current flow through shackled birds and b) may be at risk of receiving electric shocks via contact with shackled birds as they pass. The escaped bird must be removed as soon as safely possible. The shackling of conscious birds must immediately cease and the shackle line must stop. Birds which have already begun passage through the waterbath must immediately receive a neck cut, if they are stunned. The electrical supply can then be switched off and the escaped bird carefully retrieved. The escaped bird must be immediately stunned and killed with a humane back-up method; it must not be reshackled.

Figure 18. A broiler chicken's head is trapped against a side panel of a waterbath.

The bird will experience current flow because its body is in contact with the water; however it may not be rendered unconscious and insensible to pain because its head (and therefore brain) are not in the water. The waterbath side panels are too close together and must be moved apart to prevent this situation occurring.



The leg-shackle-earth interface

The contact points between a bird's legs and the shackle is likely to contribute the most resistance within each electrical circuit. Therefore birds must not be shackled with any items around their legs (eg straw) that might further increase resistance. If the total current passing through a constant voltage waterbath begins to drop as stunning progresses throughout the day, it is possible that feathers, grease and dirt are building up on the shackles, causing resistance to increase. To prevent this, shackles must be regularly cleaned throughout the day. Ideally, just before the shackles return to the live-bird shackling station, the shackles must pass through a wet cleaning system to remove feathers, dirt and any severed feet retained in the shackle. If the cleaning system fails to effectively remove severed feet, shackling staff must remove them manually before loading a conscious bird into that shackle; otherwise the quality of the stun is likely to be compromised. If shacklers continually have to remove severed feet, then the cleaning system should be repaired, or replaced with a more effective model.

Shackle washing serves an additional purpose. Although the birds' legs are touching the shackles, wide variation in resistance still occurs. Shackles must always be dripping wet when birds are hung into them because the water should help to form a better contact between the leg and the metal, reducing the variation in resistance and therefore may improve the immediacy of stunning (Figure 19). If empty shackles are wetted prior to birds being loaded into them, spraying occupied shackles with water at the leg-shackle interface, just prior to birds entering the waterbath is unlikely to have



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a significant effect on resistance and is therefore not necessary (Perez-Palacios & Wotton, 2006; AWTraining, 2008). If occupied shackles are sprayed with water at the leg-shackle interface, just prior to the entrance to the waterbath, then it is critical that sprays do not: a) disturb birds on the shackle line, especially as they enter the waterbath (eg the spray should not get water in birds' eyes); b) cause birds to receive pre-stun electrical shocks; or c) wet birds' plumage and bodies too much because this may create a **shunt** and current may flow over the exterior of the head and body instead of through the brain and heart (Bilgili, 1992; Gregory & Wotton, 1992b). It is important to use saline water for all these purposes because this increases conductivity, relative to clean water (Bilgili, 1992; Perez-Palacios and Wotton, 2006).

The accumulation of a type of scale on shackles (Figure 20), most likely an electrolytic build-up of biological material such as grease/fat from the birds' legs (P. Berry pers. comm. 2015), can sometimes dramatically increase the resistance within a circuit and can make the difference between effective and ineffective stuns. Therefore, as well as being cleaned with water and wire brushes, the shackles (and any other scale-susceptible equipment, eg electrodes) must be cleaned with an acid at least once a week to help prevent the build-up of scale. Monitoring equipment for scale is critical and a shackle must be immediately replaced if it cannot be descaled sufficiently.

High-voltage electrical parameters are advantageous for poultry welfare at slaughter (read the section '**Parameters for stun-killing**'). If high-voltage electrical parameters are used, with time, carbon can build up on the shackles, resulting in poor conductivity between the legs and the shackle. The shackles must therefore be regularly cleaned in an acid bath to restore normal electrical contact (S. Wotton pers. comm. 2014).

After stunning, abattoirs can monitor birds' legs for burns at the leg-shackle contact points. Burns may indicate increased or localised resistance, possibly through poor electrical contact, eg improper electrode maintenance (EFSA, 2004) or heavily-scaled shackles.

Figure 19. The effect of wetting a shackle on conductivity.

A dry shackle has a higher resistance than a wet shackle. Wetting the shackle prior to shackling a bird in it, may also form a better seal between the shackle and the bird's legs, helping current to flow more easily and more quickly through the bird, providing a better quality of stunning. Image: Paul Berry Technical Ltd.

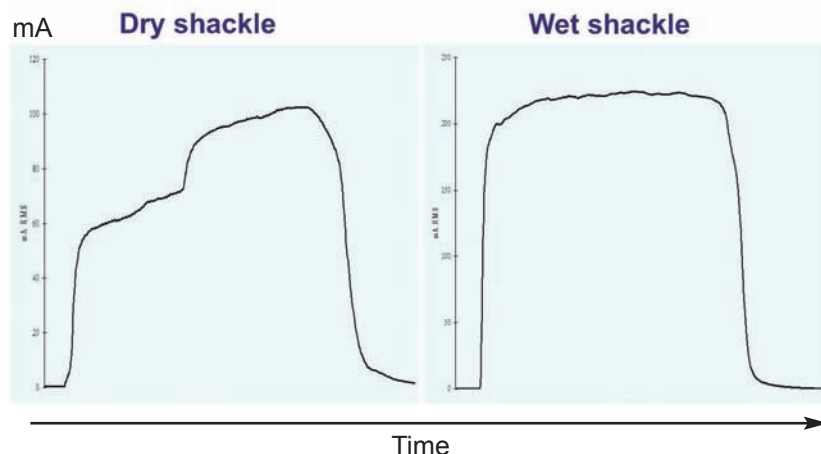


Figure 20. Brown scale on a leg-shackle contact point.

Scale must be removed from all contact points if stunning is to be effective. Image: Paul Berry Technical Ltd.





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All other associated equipment must also be suitably cleaned and maintained to ensure it remains of a low resistance. Any damaged (eg rusted, distorted or broken) equipment (including the submerged electrode, shackles and the earthed rubbing bar) may not conduct the current properly and must be replaced.

The second electrode, ie the earthed rubbing bar, must be in firm and constant contact with each metal shackle in which a bird is restrained, for the entire duration that each bird's head is in contact with the electrified water or wet plate. This includes when the shackles move rapidly, ie when birds swing off an entry ramp into the water, or during disturbance (eg if birds flap as they enter the water they can pull their shackle, and the shackles of other birds, away from the earthed rubbing bar). Similarly, make sure occupied shackles do not overlap onto occupied or unoccupied shackles, because this may reduce or alter the flow of current through a bird. If a shackle does not have continuous contact with the earthed rubbing bar, a bird will receive an intermittent flow of current which is also likely to be below the required minimum amplitude. Such poor current flow is unlikely to effectively stun a bird, particularly if it occurs at the entrance to a waterbath, in which case it may simply cause pre-stun shocks in an otherwise-conscious animal. Repeated applications of electricity may also have an adverse effect on carcass quality (Rao *et al*, 2013).

To ensure physical contact is continuously maintained between the shackles and the earthed rubbing bar:

- The bar should be installed so it passively pushes against the shackles (Figure 21). Gravity and the weight of the birds keep the shackles against the earthed rubbing bar.
- Abattoirs can install two earthed rubbing bars in very close proximity, so the bars trap the shackles between them (Figure 22) and ensure each shackle is always in contact with at least one bar. Such paired earthed rubbing bars should also prevent shackles overlapping.
 - One of the bars can also be sprung so it continually puts a degree of pressure on the shackles, keeping them firmly in place against both bars.
- The earthed rubbing bar(s) and the shackles must be monitored for signs of wear at their respective pressure points and must be replaced when contact is no longer effectively made.



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Figure 21. The entrance (left) and exit (right) of a waterbath stunner. The shackles are pushed out by the earthed rubbing bar, to enable continuous electrical contact.



Figure 22. Use of twin earthed rubbing bars to secure continuous physical contact with the shackles. Images: Paul Berry Technical Ltd.

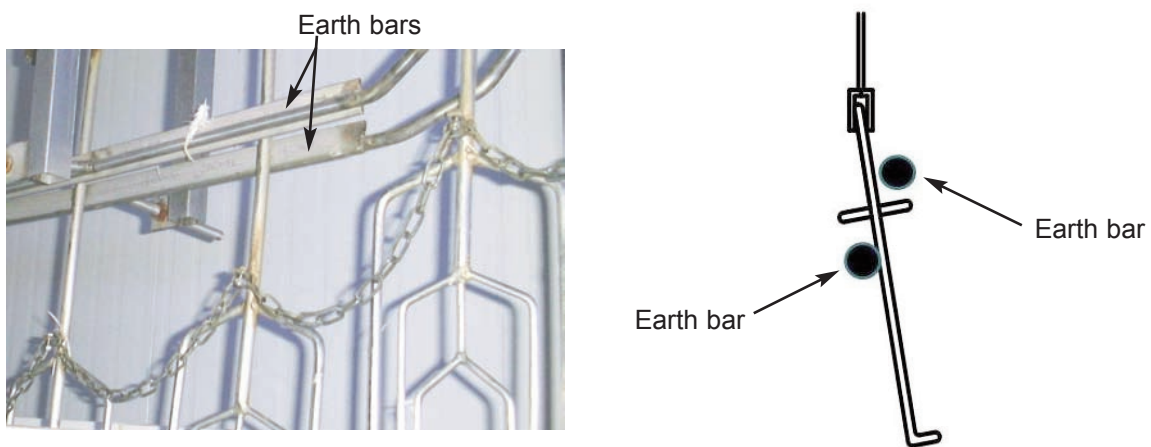
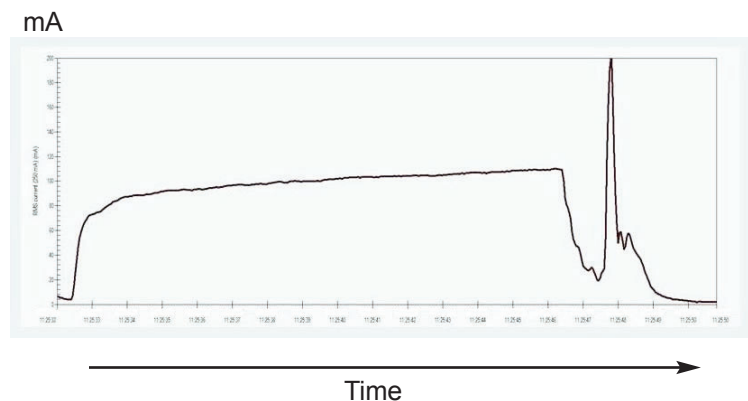


Figure 23. A current profile displaying a current 'spike' as a bird exits a waterbath stunner.

Image: Paul Berry Technical Ltd.





Critical control points of electrical contact in a waterbath system

- Earthed rubbing bar interface with shackle
- Shackle interface with a bird's legs
- Bird head interface with water/electrode

Maintaining good quality electrical contacts and controlling resistance in a waterbath system

- Install the earthed rubbing bar so it is pushing against all occupied shackles.
- Use a pair of earthed rubbing bars to secure and maintain constant contact with the shackles as birds enter, and whilst they are in, the electrified water.
- Ensure shackles are free from dirt, straw, feathers, severed feet and scale.
- Pre-wet empty shackles with a saline water spray immediately before the start of the shackling station.
- Ensure a firm fit between each leg and the shackle. Regularly monitor leg position in shackles to ensure it is optimum. If a significant proportion of birds is improperly shackled (eg have only one leg shackled), the gauge of the shackle slot may be inappropriate or the line speed may be too fast for the shacklers to work effectively, in which case the line speed should be reduced.
- If a fine saline solution is briefly sprayed onto the interface between the birds' legs and the shackles immediately before the birds enter the electrified water, make sure the spray is targeted *only* at the interface between each bird's legs and its shackle and that the spray is not soaking the birds' bodies and plumage.
- Keep the birds' bodies as clean and dry as possible, to enable current to flow through the brain and body interior as much as possible.
- Space birds far enough apart on the shackle line to prevent bodily contact, including if the wings flap or are held open. This may reduce bird disturbance, carcass damage and prevent the formation of lateral current pathways between birds during application of electricity.
- Installing a live electrode that is within 5 cm of the birds' heads may reduce the need to salt the water, depending on the conductivity of the local tap water.



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- Salt should not be added to the electrified water unless it is *absolutely necessary* (eg if the fresh, clean water used at the start of a shift is of extremely low conductivity). There are no published recommended electrical conductivities for the water in electrical waterbaths but a saline solution of approximately 500 microSiemens per centimetre ($\mu\text{S}/\text{cm}$), measured at 18°C, was reported to be sufficient for stunning (Schütt-Abraham *et al*, 1991).
- Ensure each bird's whole head is immediately and completely submerged in the electrified water (and preferably touching the electrode) and that it remains so until the bird is withdrawn from the waterbath for bleeding.
- Ensure the connection between the submerged electrode and its electric lead are not corroded or otherwise damaged or loose.
- As the stunned birds exit the stunner, the shackle line should lift their entire bodies (including heads) clear of the end panel (Figure 5B), to prevent contact. Although repeat application of current at the waterbath exit may not necessarily pose a welfare problem in unconscious birds, any current 'spikes' (Figure 23) may damage the carcass.



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The effect of electricity on an animal

In Europe, EC Regulation 1099/2009 allows electrical waterbaths to be used for stunning poultry, provided the exposure of the entire body to a current generates a generalised epileptic form on the EEG.

Whilst electricity is applied across an animal's whole body, the body will typically be rigid and still. If the current passes through the animal's brain and if the parameters are appropriate for stunning, the brain is expected to show a certain type of electrical activity which, in a laboratory, can be viewed using an **electroencephalogram (EEG)** or electrocorticogram (ECoG). After application of electricity, a bird is likely to be unconscious and insensible to fear and pain if its EEG displays generalised epileptiform activity (EFSA, 2013a) characterised by high amplitude, low frequency polyspikes, followed by a quiescent (suppressed) isoelectric EEG where the post-stun EEG power is < 10% of the pre-stun power (EFSA, 2004; Raj *et al* 2006c; EFSA, 2012). (A quiescent EEG indicates a complete depolarisation (inhibition) of the neurones in the brain.) This duration of epileptic plus quiescent brain activity must last for at least 45 – 60 seconds (eg EFSA, 2012), to allow enough time for death to occur by whichever chosen means. If the EEG does not become epileptiform and quiescent, and for a sufficient duration, then a bird cannot be classed as effectively stunned (Schütt-Abraham *et al*, 1983) because it may either never become unconscious or it may recover consciousness too soon, before death can occur. At the proof-of-concept stage, and in compliance with legislation protecting the welfare of animals used for scientific purposes, when scientists assess which combinations of electrical parameters are suitable for effective stunning, they often apply the test current (to a very small number of birds) for a shorter-than-normal duration (eg for one second) to assess whether the parameters can *immediately* render a bird unconscious. If the parameters cannot achieve unconsciousness immediately, they are unsuitable for bird welfare, even if a longer application time can result in an eventual loss of consciousness, because the bird may experience pain and distress during induction of unconsciousness. (Note: this type of experimental animal welfare assessment requires advance permission from the government in many countries and is not suitable for routine slaughter of birds, due to the potential for rapid **recovery** of consciousness under these specific circumstances.)

There are interactions between the effects of the various electrical parameters that might be used to attempt to stun birds. Different combinations of parameters determine whether epileptiform activity is expressed and the degree of suppression of the EEG (ie whether a bird immediately becomes, and remains, unconscious for long enough). The electrical parameters that appear to be better at generating epileptiform and quiescent EEGs are generally high amplitude, low frequency, sinusoidal (sine) AC currents. For example:

- Sine waves appear to be more effective than other waveforms and may even require lower amplitude currents to achieve the same effect in the EEG (Prinz *et al*, 2012).
- At a given amplitude of current, high frequencies are associated with fewer birds experiencing epileptiform activity and quiescent EEGs (Raj *et al*, 2006c). In an attempt to compensate for this, the amplitude of the current can be increased at a given high frequency; however it may still be associated with comparatively faster

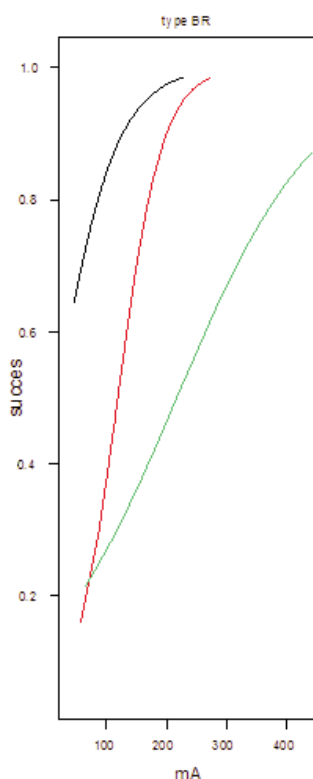


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recovery of normal EEG activity (Raj & O'Callaghan, 2004a). Statistical modelling suggests the chance of a successful stun reduces progressively as frequency increases, even if current is also increased (Figure 24: Hindle *et al*, 2009). Therefore, in terms of animal welfare, high frequencies are unlikely to perform as well as low frequency currents. (In addition, the higher currents required at higher frequencies tend to still be associated with defects in carcass quality.)

- None of the DC parameter combinations researched so far have produced unconsciousness (as assessed by EEG) in 100% of birds. DC appears to be less capable than AC, at inducing effective stunning, even if the period (read the summary of electrical terminology on page 30) of the DC and AC currents is the same and if the amplitude of the DC current is higher. The duty cycle must be at least 50% (a 1:1 mark:space ratio) in order to generate an effective stun, for a sufficient time, in a majority of birds (Raj, 2004; Raj *et al*, 2006b; Hindle *et al*, 2009). For example, at 200 Hz pDC it is necessary to use at least a 50% duty cycle with an average current of 200 mA per bird, to ensure epilepsy occurs in 80% of birds (Raj *et al*, 2006b). However this percentage is not high enough to be considered acceptable for animal welfare.

Figure 24. Example of a statistical model that indicates the probability of a successful stun in broiler chickens, when applying a square wave AC for 5 seconds, at 50 Hz (black line), 400 Hz (red line) or 1000 Hz (green line). There is a significant difference in the chance of a successful stun at different frequencies. When using relatively low currents, higher frequencies have a lower chance of a successful stun, compared to lower frequencies. For example, at a current of approx. 120 mA, the probability of a successful stun is just under 90% at 50 Hz, just over 50% at 400 Hz and approx. 30% at 1000 Hz. At 1000 Hz, as current amplitude increases, there is a much lower rate of increase in the chance of a successful stun, compared to the other frequencies. Therefore, when using lower current amplitudes, 400 and 1000 Hz provide a much lower chance of a successful stun than 50 Hz does. Image: adapted from Hindle *et al*, 2009.



Waterbath and wet plate stunners are available as single phase (commonest) or multi-phase systems, where, respectively, either only one electrical treatment of one waveform and current amplitude may be applied, or where, typically, two treatments of differing waveforms and/or current amplitudes may be applied consecutively. The effects of multi-phase systems on brain activity are largely scientifically unknown.



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However, it appears that all systems (single- and multi-phase) must use in the first (or only) phase, parameters scientifically shown to generate immediate, effective stunning (Prinz, 2009). Thereafter, any additional phases must be capable of continuously maintaining the unconscious state until death has occurred. It is unacceptable for a bird to be electroimmobilised by inadequate electrical parameters in the first phase and then rendered unconscious in a second or further phase.

A threshold current must be immediately reached, or exceeded, in order to initiate immediate unconsciousness.

If too little current enters the brain (because the current delivered is below the minimum recommended amplitude or the current pathway is inappropriate, eg the head is not submerged in the electrified water) then electroimmobilisation may occur. Even if the bird dies as a result, this is unacceptable and inhumane.

When choosing electrical parameters to stun poultry, the HSA strongly advises operators to follow scientific recommendations, appropriate to animal welfare (EFSA, 2004).

Unfortunately, electroimmobilisation may physically resemble effective electrical stunning because muscle function is inhibited, and physical reflexes are suppressed, by the current (particularly if the current passed through the whole body, as indeed it would in a waterbath or wet plate stunner, eg Prinz (2009)). Therefore it may be difficult to identify, using animal behaviour alone, a paralysed, conscious animal from a stunned, unconscious animal. Behavioural assessment of the appropriateness of certain parameter combinations, should only be relied upon when used in conjunction with EEG analysis (von Wenzlawowicz & von Holleben, 2001). Therefore abattoirs should follow evidence-based recommendations for animal welfare from the scientific community, when deciding how and which electrical parameters to apply to an animal, for the purpose of stunning and successfully rendering it unconscious until death supervenes (EFSA, 2004).

The mode of current application and the electrical parameters used, can determine whether an animal will die (stun-killed) whilst unconscious, or if it has the potential to recover consciousness after the prolonged, effective stun has run its course.

Electronarcosis is a temporary, fully-reversible state. Normal brain function is disrupted for a short time only and, unless killed by another method, the animal will regain consciousness, usually within one minute. (Note: even if there is the potential for an animal to regain consciousness, this must not be allowed to actually happen (to ensure the animal's welfare remains protected). Immediately after stunning, a killing method (eg neck cutting) must be applied to ensure the birds die (eg of blood loss) before there is any possibility of them recovering consciousness.)

Restricting a stunning current's pathway so that it travels through only the head (brain)



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of an animal (eg by using head-only electrical stunning equipment), is far less likely to result in a stun-kill (ie death by electricity) than when the stunning current is also allowed to pass through the animal's body.

A stun-kill can occur if a current passes through the heart of an animal. The muscle of the heart is more sensitive to certain, relatively low frequencies, eg 50 Hz. If a low-frequency current of a large-enough amplitude passes through cardiac muscle, an unco-ordinated condition known as cardiac ventricular fibrillation is likely to occur. The ventricles (ventral chambers) of the heart cease to beat rhythmically and instead contract rapidly and irregularly (EFSA, 2004). Cardiac ventricular fibrillation (CVF) reduces cardiac output, relative to normal levels (EFSA, 2004), and, without correction (eg defibrillation), CVF typically leads to cardiac arrest, which is irreversible, and the heart stops pumping blood round the circulatory system. This rapidly prevents oxygenated blood from reaching the brain (**ischaemia**), thereby killing the brain cells and preventing recovery of consciousness. Electrical stunning systems that apply current across the entire body, can be operated using electrical parameters that should reliably cause the majority of birds to die from a cardiac arrest.

When attempting to stun-kill a bird with electricity, it is still necessary to use appropriate electrical parameters that will cause immediate unconsciousness, prior to, or simultaneous with, the occurrence of death. It is possible that insufficient current amplitude, or other inappropriate electrical parameters, can cause death without associated unconsciousness. Application of electricity in a manner that does not induce unconsciousness (eg if current bypasses the brain or if insufficient current is provided to the brain) cannot be considered humane, even if the animal dies as a result. For example, at a 50% duty cycle of 200 Hz pDC, 200 mA average current per bird caused 60% of broiler chickens to experience cardiac arrest; but, of these **fibrillated** birds, only 67% displayed effective stunning, as assessed by EEG (Raj *et al*, 2006b). This suggests that 33% of the fibrillated broilers may have suffered a potentially painful electroimmobilisation, followed by death by CVF, rather than being rendered unconscious. Even when using AC, turkeys may be particularly susceptible to CVF at current amplitudes lower than that needed to reliably generate unconsciousness (Gregory & Wotton, 1991a).

Compared to using stun-only electrical parameters plus neck cutting, using stun-kill parameters is advantageous for animal welfare because it starts the process of dying at the same time as stunning (Wilkins & Wotton, 2002). This reduces the risk of animals regaining consciousness before, or as, they receive a neck cut and bleed out, particularly if the neck cut is delayed and/or inaccurately performed (Gregory & Wotton, 1988b). Death by electricity therefore acts as a 'safety net' for ensuring birds cannot recover if, occasionally, neck cutting is inaccurate and results in inadequate bleeding.

At the same current amplitude, but at progressively higher frequencies, there is a progressively reduced probability of death. Therefore, if a high frequency is used and the operator wishes to achieve a stun-kill, the amplitude of the current must be significantly increased. Above a certain frequency, death by electricity may become impossible for the majority of animals.

Parameters for stunning

When a stunning method is applied correctly, the stunning parameters should achieve an effective stun in 100% of individuals. Even a very small percentage of failed stuns



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will account for a large number of individual birds potentially suffering because poultry are slaughtered in vast numbers around the world.

Individual birds can be effectively stunned in waterbaths using a broad range of amplitudes of current, but the difficulty is ascertaining which parameters *reliably* achieve effective stunning in 100% of birds. EFSA (2012) could not identify any parameter combinations that, in all tests, resulted in 100% of birds being effectively stunned.

It does not appear possible to specify one current amplitude, for all frequencies and waveforms, that will ensure 100% effective stunning (Raj, 2004). Abattoirs should be aware that, to achieve an equivalent effect on a bird's brain activity, different waveforms may require greater amplitudes of current. For example, whilst 150 mA per bird at 200 Hz sine AC may result in 100% of sampled broiler chickens experiencing epileptiform activity, 150 mA at 400 Hz sine AC may not result in 100% effective stunning (Raj *et al*, 2006c). Compared to sine AC, square/rectangular AC waves appear less effective (Prinz *et al*, 2012) and may require greater current amplitudes to induce 100% effective stunning.

In Europe, waterbaths must operate using electrical parameters specified by EC Regulation 1099/2009 (Table 4). However it should be noted that sine AC frequencies of 600 Hz or more, at 200 mA per bird, have failed to induce epilepsy and/or a sufficient duration of quiescent EEG in 100% of broiler chickens tested (Raj *et al*, 2006c). Application of 100 - 200 mA per chicken, using frequencies higher than 200 Hz sine AC sometimes failed to induce sustained quiescent EEGs, especially at, and

Table 4. Minimum current amplitudes per bird for electrical waterbath stunning, as required since January 2013 by European Council Regulation 1099/2009.

Frequency (Hz)	Chickens (mA)	Turkeys (mA)	Ducks & geese (mA)	Quails (mA)
< 200	100	250	130	45
From 200 to 400	150	400	Not permitted	Not permitted
From 400 to 1500	200	400	Not permitted	Not permitted

Table 5. Additional suggestions for good practice electrical parameters.

Waveform & frequency (Hz)	Chickens (mA)	Ducks (mA)
Sine AC 50 - 199 Hz	100 RMS	
Sine AC 200 Hz	150 RMS	
Sine AC 400 Hz	200 RMS	
Square AC 50 Hz		170 RMS*

* it is possible that ducks and geese may require a greater current amplitude for sine and square wave frequencies up to 200 Hz but scientific evidence is lacking (Hindle *et al*, 2009).



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above, 800 Hz (Raj *et al*, 2006c). Therefore, in the interests of bird welfare, it may be preferable to use frequencies of 50 - 200 Hz, maximum, for chickens and perhaps even for turkeys. Based on available research using EEG analysis of unconsciousness (Raj & O'Callaghan, 2004b; Raj *et al*, 2006c), abattoirs may wish to consider using the additional measures in Table 5.

There are no published recommended currents for inducing unconsciousness in 100% of guinea fowl. As a precaution, until scientific evidence becomes available, the minimum current amplitude might be at least 100 mA RMS per guinea fowl, at 50 Hz sine AC. Although the birds are relatively light in weight and have naked heads, they are older than some other species at the time of slaughter and so their skulls and thin legs may have developed a relatively high resistance to electricity.

To increase the likelihood of an effective stun and a prolonged duration of unconsciousness, each bird must be immersed in the electrified water for a sufficient time. The length of a waterbath and the line speed directly affect the duration that a bird is exposed to a current. The fastest line speed used by an abattoir must still be capable of administering the recommended minimum duration of current application (Schütt-Abraham & Wormuth, 1991). Recommendations include:

- At least four seconds (EC Regulation 1099/2009 and OIE, 2014)
- At least eight seconds when using high frequencies above 100 Hz (Defra, 2007)
- At least 10 seconds when using 50% pDC (Prinz, 2009)

Note: increasing the duration of application of current may only have a marginal effect on the efficacy of stunning and it cannot compensate for inadequate electrical parameters (Schütt-Abraham & Wormuth, 1991; Hindle *et al*, 2009).

Parameters for stun-killing

If abattoirs wish to induce a stun-kill in as close as possible to 100% of birds, Table 6 suggests parameters, based on scientific research. At high frequencies (above 100 Hz: Defra, 2007), and/or if using certain modified waveforms, it is unlikely that the majority of birds will undergo cardiac arrest. Therefore low frequencies must be used. As well as choosing the correct frequency, the current amplitude must also be appropriate for inducing CVF. Usually, increasing the proportion of birds that experience a stun-kill requires an increase in the current amplitude (turkeys: Gregory & Wilkins, 1989a; ducks: Gregory & Wilkins, 1990), to a value beyond that necessary for effective [but recoverable] electronarcosis. For example, at 50 Hz sine AC, 105 mA RMS and 148 mA RMS may produce CVF in approximately 90% and 99% of broiler chickens, respectively (Gregory & Wotton, 1987; 1990).

Within a given set of electrical parameters, the incidence of CVF may vary between species, types, sexes and even batches of birds (Gregory & Wotton, 1990; 1991b; 1992b; 1994; Schütt-Abraham & Wormuth, 1991; Wilkins *et al*, 1998). For example, compared to lighter-weight turkeys (ie females), heavy, male turkeys may be less susceptible to CVF because their greater mass of skeletal (breast) muscle may reduce the amount of current that can reach the heart (Mouchonière *et al*, 1999).

If a constant voltage stunner is used to apply the parameters in Table 6, or if a bird



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manages to avoid the electrified water for most of the length of a waterbath, there is a greater risk of some birds not receiving sufficient current, or for the necessary duration, to induce CVF. For any bird that does not die as a result of waterbath stunning, effective neck cutting remains critical. Therefore all poultry slaughtered using electrical waterbath or wet plate stunners, at all electrical parameters, should have both carotid arteries and both jugular veins severed, as standard routine practice. This may also assist with bleeding the carcass as fully and quickly as possible (particularly if the birds have experienced CVF) and may reduce the amount of blood retained in the carcass (Gregory & Wilkins, 1989b) during further processing.

Table 6. Electrical parameters that may induce CVF in approximately 100% of birds. An application time of at least 10 seconds is likely to be suitable. The current amplitudes required for waterbath stunning by EC Regulation 1099/2009, induced CVF in 100% of turkeys (Gregory & Wilkins, 1989a) and quail (Gregory *et al*, 1991), when applied at 50 Hz sine AC.

Note: if, for reasons of disease control, operators plan to kill poultry using a waterbath and will not bleed the birds after stunning (to limit spillage of potentially-infected bodily fluids), then, to increase the probability that all birds will die, the current amplitudes must far exceed those in this table. For example, at least 400 mA RMS per bird may be appropriate (broiler and egg-laying chickens: Gerritzen *et al*, 2006; turkeys, ducks: M. Gerritzen pers. comm. 2014).

Bird type	Minimum current amplitude (mA)	Waveform	Comments eg based on ...
Chicken	170* RMS	Sine AC 50 Hz	highest amplitude survived in Gregory & Wotton (1988a)
	120+ RMS	Square AC 50 Hz	Hindle <i>et al</i> (2009; 2010). * 170 mA may be suitable
Guinea fowl	86 RMS	Sine AC 50 Hz	Schütt-Abraham & Wormuth, 1988
Duck	255+ RMS	Sine AC 50 Hz	Gregory & Wilkins (1990)
	235+ RMS	Square AC 50 Hz	Hindle <i>et al</i> (2010)
Goose	225+ RMS	Sine AC 50 Hz	Schütt-Abraham & Wormuth (1988)



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Monitoring stunning parameters

Once the ideal parameters are selected and programmed into a waterbath system, it is necessary to regularly and routinely check the equipment is consistently achieving these aims, using the control panel of the stunner and additional monitoring equipment. Operators must ensure that the minimum value of the range of current amplitudes estimated or measured, is at least the recommended or legally-required minimum current amplitude per bird.

EC Regulation 1099/2009* requires waterbaths to “be fitted with a device which displays and records the details of the electrical key parameters used. These records shall be kept for at least one year”.

*abattoirs with relevant equipment that was in use prior to 1 January 2013 have until 8 December 2019 to comply with Article 14(1) and Annex II of Regulation 1099/2009, including the requirement above. (Abattoirs, layouts or equipment constructed after 1 January 2013 must apply the requirements immediately.)

Stunner control panel

The frequency and the amplitudes of the total current and voltage passing through a waterbath must be clearly displayed by a large frequency meter, **ammeter** and **voltmeter** respectively. Meters must be positioned so they are visible to personnel, including the slaughterperson(s) responsible for checking effective stunning and for neck cutting, so they can clearly see whether sufficient current is passing through the waterbath, without leaving their post or having to turn around. For accuracy, meters should ideally be digital and display all parameters to two decimal places. The units should be clearly indicated, eg Hz or kHz, A or mA. Voltmeters and ammeters must also be capable of displaying correct voltages and currents in RMS, average and peak units, for all waveforms the system can supply (Schütt-Abraham & Wormuth, 1991); the control panel must automatically indicate which unit is in-use at any given time. For each different bird type slaughtered, checks of the parameters should be performed at least once per batch, and certainly if the parameters are altered by the operator between batches. This is particularly critical for constant voltage, multi-bird waterbaths, which must be carefully adjusted to attempt to obtain the correct current amplitude per bird. For example, when operating a constant voltage stunner, the actual voltage required may in fact be greater than was estimated (read the section ‘**Constant voltage versus constant current**’). Therefore, at the start of slaughtering each batch of birds, the ammeter must be consulted and the voltage adjusted, as necessary, until the ammeter meets the estimated target. Regular monitoring of the ammeter is key to determining the typical total resistance for each stunner and each type of bird processed; operators can consequently adjust their voltages, as appropriate.

It is important that operators are aware what an ammeter reading refers to. Most ammeters record the total current flowing through the entire waterbath system (not through each individual bird). An estimate of the current supplied to each bird can be manually calculated by dividing the total current by the number of birds within the water at any given time (eg Figure 15A). However, this method will not provide an accurate estimate of the current per bird because a) the number of birds in the water at a given time varies with moving shackle lines and shackling practices, and b) there may be variation in the total resistance of each branch of the circuit (eg the waterbath equipment, each individual bird (Wotton & Gregory, 1991c) and the quality of the



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electrical contact). For example, Sparrey *et al*'s (1992) model indicated -25 to +18% variation in the average current amplitude in a constant voltage stunner, assuming there was no conductive contact between adjacent birds. Some ammeters can display an estimate of the current received per bird; however, again, this is unlikely to be helpful unless the system can continuously and accurately monitor the actual number of birds in the water and adjust accordingly, its estimate of the current amplitude per bird. A stunner control panel, and its recording device, should ideally provide a reading of the number of resistors (ie birds) in the water at the time a particular current reading is taken; this may allow more precise estimations of the current received per bird, whether manually or automatically calculated. Ideally, control panels should record the actual parameters received by each and every individual closed branch in a circuit at a given time (ie of each bird in the water), thereby avoiding the need to estimate, or extrapolate to, the current received by each bird.

In an open circuit (ie with no birds in the electrified water), the ammeter of the stunner control panel should read 0 A (Schütt-Abraham, 2004). If the ammeter reads a value greater than zero, either the ammeter needs recalibrating, or current is being lost somewhere within the circuit. In each case, birds are at risk of receiving a lower-amplitude current than intended. An electrician must, if necessary, adjust the control panel ammeter and/or identify if, and where, the loss of current occurs and prevent it (eg by replacing corroded electrodes or connections).

Additional monitoring equipment

In-line, stand-alone meters, or remote stun monitors (Figure 25), calculate the estimated current per bird more objectively and can also confirm the stunner control panel meters are accurate. Remote stun monitors can record the waveform, frequency, peak and RMS voltage and current. The device is essentially a resistor that simulates the resistance of a bird. A stun monitor can be shackled in place of a bird and passed through a waterbath either on its own or with live birds in other shackles (the latter scenario will reflect normal processing). The stun monitor records and displays the current amplitude flowing through it and the duration of application. A stun

Figure 25. A remote stun monitor. This equipment simulates the resistance of a live bird and provides an estimate of current amplitude received per bird (Wotton & Wilkins, 2004).
Image: AGL Consultancy Ltd.



Figure 26. A stunner evaluation device. This equipment measures the actual parameters passing through a live bird.
Images: Paul Berry Technical Ltd.





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Figure 27. Examples of data downloaded from a remote stun monitor to a computer. The stun monitor was passed through a waterbath operating at 400 Hz sine AC. The characteristic undulating curve indicates the measured waveform is sinusoidal. The values for the “max” or peak voltage and current, and for the “eff” (effective) or RMS voltage and current, are given on the right side of each screen image. The graphs show how the values of the “max” or peak electrical parameters (eg voltage - red line; current - blue line) change over time.

Each screen image (a, b c) illustrates the measured parameters when the stun monitor was programmed to simulate three different resistances of:

- a) 1000 Ω
- b) 1500 Ω
- c) 2500 Ω .

(The actual value achieved is displayed on the right side of each image as “Reff”.)

The images show that, whilst the equipment provides a constant voltage (red line) at each level of resistance, the current amplitude (blue line) progressively reduces from:

- a) 127 mA RMS to
- b) 86 mA RMS to
- c) 51 mA RMS.

This illustrates how birds with higher resistances may receive lower current amplitudes.

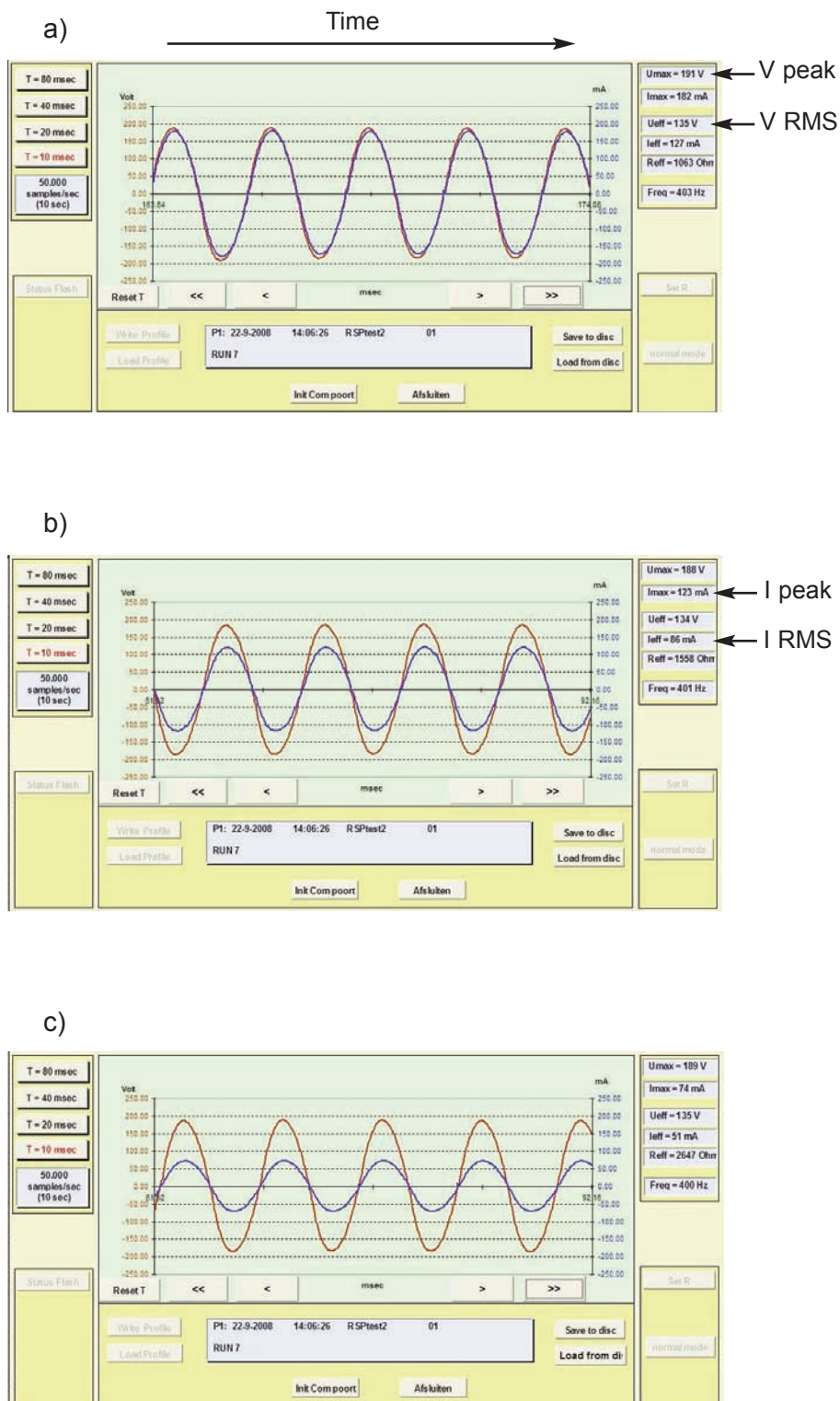


Image: adapted from Hindle *et al*, 2009; stun monitor: RSP BV, Netherlands.



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monitor must be pre-programmed with the average and maximum likely resistance that represents a live bird of the species, breed or sex being slaughtered (eg as shown in Figure 27a,b,c). If required, Table 2 provides resistances that can be used to program a stun monitor. (The resistor must be calibrated frequently.) If the displayed current amplitude is below that required per bird, by law or in other recommendations, then the voltage of the stunner must be increased to provide enough current (assuming the abattoir is using a constant voltage stunner and all electrical contacts are confirmed to be satisfactory). Abattoir personnel should use remote stun monitors at least daily, before live birds are slaughtered and whilst live birds occupy all other shackles in a waterbath. Bear in mind that devices that display the current amplitude of just one branch of a circuit (ie one occupied shackle in a multi-bird waterbath stunner), which has a constantly changing resistance, can be misleading (EFSA, 2004). At least 15 'runs' should be carried out to determine the average current and any variation (adapted from Berry *et al*, 2002). The information can be downloaded to a computer (Figure 27a,b,c) for long-term monitoring and verification of a stunner's performance under load. This may be helpful in identifying problems, eg if current amplitude is slowly but progressively reducing due to a build-up of resistance within the electrical circuit, eg perhaps due to scale or carbon on the shackles.

When estimating the current amplitude per bird using either the stunner control panel display or a remote stun monitor, there is a degree of error involved because of the assumed value of resistance. Therefore operators are strongly encouraged to also use, at regular intervals, a device that can measure [during normal processing] the actual bird's resistance and the actual current amplitude passing through that bird (Figure 26).

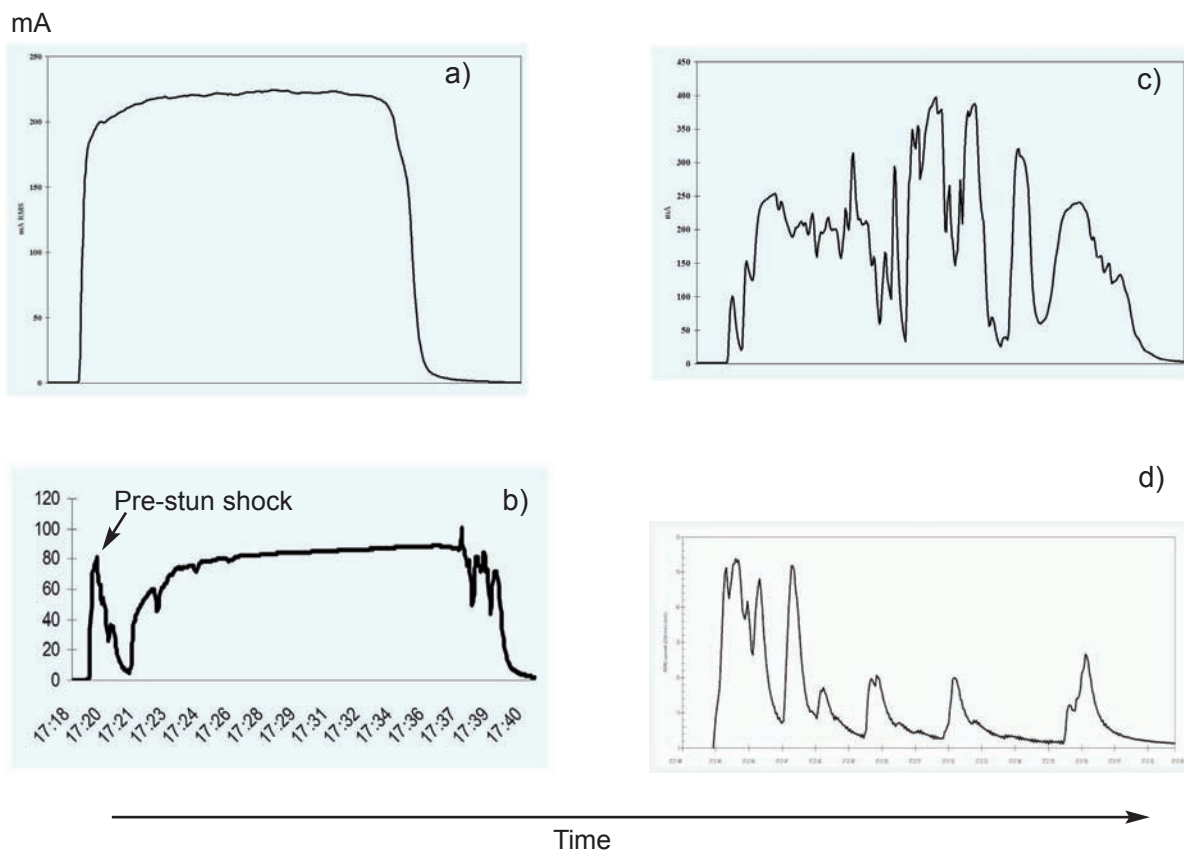
It is useful if a device can continuously record the entire duration of electrical application to a simulator or a live bird and display a resultant current profile. An ideal current profile immediately rises to a continuously-sustained plateau at the intended current amplitude (eg Figure 28a). Profiles may enable operators to identify any aberrations that might indicate ineffective stunning, eg rapid, transient 'spikes' of current flow may indicate pre-stun shocks (Figure 28b) or poor physical electrical contact or poor electrical conductivity (Figure 28c,d). The time in the recording at which an aberration occurs can be used to locate, on the shackle line, where the problem arises, and therefore hopefully the cause (Berry *et al*, 2002).

Current profiles also enable operators to accurately monitor the duration of current application for a representative sample of birds (ie the time that each bird's head is in contact with the electrified water or wet plate electrode). This time will not necessarily be the same as the passage time (the time the bird spends within the panels of a waterbath), which in some poorly-designed installations can be the only means of estimating the duration of current flow because an assessor cannot properly see into the waterbath. Whilst a shackle conveyor consistently controls the passage time for each bird, if a bird's head is not immediately submerged in the electrified water, it will not receive the same duration of current application as other birds (Schütt-Abraham & Wormuth, 1991). Larger species of bird and/or typically restless types may experience a shorter duration of application (Schütt-Abraham & Wormuth, 1988). For example, Rao *et al* (2013) observed that the majority of broiler chickens that received pre-stun shocks subsequently attempted to take flight for at least four seconds of the 9.4 seconds intended dwelling-time in the electrified water.



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Figure 28. Interpreting current profiles. a) An ideal profile rises to the intended current amplitude within 100 milliseconds; b) a pre-stun shock at the start of stunning; c) intermittent contact between the shackle and the earthed rubbing bar; d) low conductivity caused by scale on the shackle. Images: Paul Berry Technical Ltd.



A hand-held, digital oscilloscope or meter can be used to verify a stunner is operating appropriately, by measuring the voltage under load (ie when birds are in the electrified water), frequency and waveform. Oscilloscopes should have a sampling rate that is fast enough to accurately and correctly display the waveform (EFSA, 2004), including any complex detail. (For example, at high frequencies waveforms may distort and feature pulses within the main waveform, potentially leading to measurement of multiple frequencies in a single waveform.) Current (RMS, average and peak) can be remotely measured with a suitably specified clamp (either an adapter fitted to an existing meter, or an integrated clamp meter). It is important to make sure a clamp has sufficient accuracy when measuring low amplitude currents (because low amplitude currents are typical of waterbath stunners). If an abattoir uses pDC electrical parameters, the clamp must be capable of sensing DC.

It is important to note that there are different types of meters (eg **analogue**, '**true RMS**', '**AC+DC true RMS**'), which have different capabilities. Most meters can measure the average voltage of a pDC waveform (using the DC setting) and can read the RMS voltage of a sine AC waveform (using the AC setting). However, if an AC waveform is not sinusoidal in shape, then a 'true RMS' meter is required. If an abattoir



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wishes to measure the RMS of a pDC waveform, an 'AC+DC true-RMS' meter is necessary (relatively few meters have this setting). (Alternatively, a 'true RMS' meter can be used to measure the average voltage when on the DC setting and to provide the standard deviation of the voltage on the RMS setting and thereafter the operator can calculate the RMS pDC from the square root of the sum of the AC reading squared and the DC reading squared.) An AC+DC true-RMS meter may be more versatile for measuring a variety of waveforms and units of voltage; consult an electrical engineer for advice.

Bear in mind that the output voltage under load may be reduced compared to the voltage that can be measured in an open circuit (ie when no birds are in the water); this drop in voltage must be accounted for when programming the stunner to achieve the desired minimum current amplitude per bird. For example, Gregory & Wotton (1987) recorded an average voltage drop of 29% once systems were under load. The output voltage may fluctuate with the efficiency of the transformer controlling it, eg due to heating (Wotton & Gregory, 1991b), and abattoirs must monitor this. A transformer should have sufficient capacity so there are no appreciable decreases in the amplitude of voltage when the stunner is under load (Schütt-Abraham, 2004).

Electrical stunners, their control panels (including all meters) and stun monitors should be regularly checked to ensure they are correctly displaying the actual parameters in the stunner (Heath, 1984) and should be regularly calibrated against a factory-calibrated meter and maintained by a qualified electrician. Calibration should be performed whenever the equipment becomes inaccurate, and at least annually (OIE, 2014), preferably six-monthly (EUWeINet, 2013a) and in accordance with the manufacturer's instructions.

Indicators of the effectiveness of stunning

A waterbath stunner should not be used until a person is available to ascertain whether it has been effective in stunning the birds. Immediately after application of an electric current, and before neck cutting, animals must be checked to ensure they are unconscious. When a bird has not been effectively stunned first-time, that person must stun and kill any such birds without delay. Depending on the electrical parameters used, even in a system thought to stun-kill the majority of birds, some may have retained a normal heart rhythm. Consequently, the design of the equipment, its layout and the line speed must allow adequate checks for effective stunning, whilst ensuring these factors do not significantly delay the application of neck cutting.

Assessing the effectiveness of stunning is a very important part of the entire slaughter process. Operators must be trained to identify signs of ineffective stunning and must understand the appropriate action necessary, to immediately protect birds from avoidable suffering. Ineffectively stunned birds must not be re-shackled for waterbath stunning a second time. Instead, a humane back-up stunner should be applied immediately, eg a captive-bolt device designed for poultry.

Behavioural assessment of unconsciousness should only be relied upon if EEG analysis has already confirmed a parameter combination is effective at inducing unconsciousness. This is because research suggests that, immediately after application of electricity, the presence/absence of physical reflexes, convulsions and other behaviours may be unreliable indicators of effective stunning, particularly for



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whole-body application methods (ie waterbaths) and at high frequencies (EFSA, 2012). For example:

- whether epilepsy is induced or not, birds display physical seizures and **apnoea** (Schütt-Abraham *et al*, 1983; Raj *et al*, 2006c);
- fewer positive reflexes tend to be seen after application of low frequency and/or high amplitude currents. However, very low current amplitudes, or even multi-phase methods that combine very low amplitude, high frequency current in the first phase with higher amplitude, low frequency current in the second phase, can also suppress reflexes and convulsions, despite the EEG indicating the bird is most probably conscious (Prinz, 2009).

Assessment using a single animal behaviour may be misleading. Multiple reflexes and behaviours must be assessed in order to reach a reliable conclusion. Ideally, at any time after application of an electric current, birds should not display behaviours that might be associated with consciousness (eg rhythmic breathing).

EFSA (2013a) produced 'toolboxes' (Table 7a) of the most reliable ('sensitive'), scientific animal-based welfare indicators, designed to give abattoirs meaningful information on the efficacy of their slaughter procedures. When animals are stunned during the slaughter process, EFSA (2013a) recommend that it is more appropriate to look for outcomes of consciousness (ie failed, ineffective stunning). EFSA (2013a) recommend that operators choose at least two 'recommended' indicators for electrical waterbath stunning and thereafter may choose 'additional' indicators according to their expertise and the infrastructure of the abattoir. Applying more than one indicator (assuming they are independent of one another on a physiological basis or in terms of the checking procedure) may improve the sensitivity of monitoring and may increase the probability of detecting conscious individuals. EFSA (2013a) recommend that abattoir 'personnel' (persons performing handling, shackling, stunning, neck cutting) should sample 100% of the animals immediately after stunning, during neck cutting and during bleeding to confirm they are not conscious before further processing takes place; in addition, the AWO should periodically assess a sample of the slaughter population. (EFSA (2013b) developed a sample size calculation tool - read the '**Useful contacts**' section.) EFSA (2013a) also suggest different risk factors (Table 7b) and scenarios which can define the level of the monitoring protocol required by each abattoir, eg whether it should be a 'normal'/standard protocol (read EFSA, 2013a,b) or, if necessary, a 'reinforced'/tightened protocol until the risk is rectified. For example, the sampling frequency will need to be increased when a conscious animal is detected or when a risk factor (eg employment of new personnel) reduces the sensitivity of an indicator; in such cases, EFSA (2013a) recommend testing a tenth of the slaughter population in one observation.



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Table 7a. EFSA (2013a) indicators for electrical waterbath stunning of poultry. The marks (P) = presence and (A) = absence next to an indicator, imply when the outcome may be a conscious individual. The ‘*additional*’ indicators are relatively low in sensitivity or feasibility and are insufficient for use on their own, without the ‘*recommended*’ indicators.

Some indicator outcomes may occur spontaneously and others require intentional provocation (eg reflex testing). An indicator must be feasible to monitor and this will depend on the layout of an abattoir.

EFSA (2013a) define spontaneous swallowing as the deglutition reflex triggered by water from the stunner, or blood from the neck-cutting wound, entering the mouth during bleeding. Head shaking may be triggered by blood entering the nostrils.

Toolbox 1:	Monitoring between the exit from a waterbath stunner and neck cutting
	<i>Recommended:</i> tonic seizures (A), breathing (P), spontaneous blinking (P) <i>Additional:</i> corneal &/or palpebral reflex (P), vocalisations (P)
Toolbox 2:	Monitoring during bleeding
	<i>Recommended:</i> wing flapping (P) and breathing (P) <i>Additional:</i> corneal &/or palpebral reflex (P), spontaneous swallowing (P), head shaking (P)

Table 7b. Risk factors to bird welfare, associated with electrical waterbath stunning of poultry. Adapted from EFSA (2013a).

Component	Risk factor	Risk of poor quality stunning	Risk of poor quality assessment
Staff	a) Competence b) Experience c) Fatigue	Yes Yes Yes	Yes Yes Yes
Equipment	a) Features, eg: i) poor water conductivity ii) line speed b) Maintenance c) Presence of maintenance records (eg cleaning)	Yes Yes Yes Yes	Yes
Animals	a) Body weight b) Species/type/temperament	Yes Yes	Yes Yes
Records of monitoring procedures	Conformity in the past	Yes	Yes



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Practicalities of assessment

It is preferable to assess a bird for the effectiveness of stunning, prior to neck cutting. If a bird is examined only after neck cutting, then:

- If the bird's spinal cord is damaged by the cut, it may not be possible to properly assess its state of consciousness (Gregory & Wotton, 1986).
- Potentially, an automated neck cutter may occasionally cut a conscious bird, eg one that avoided the electrified water (Rao *et al*, 2013). This will most likely cause severe pain and suffering and is unacceptable.

Birds can be assessed for effective stunning *in-situ* in two ways. Whilst a single bird travels along a section of a shackle line, an assessor can follow it and perform a series of checks for indications of the effectiveness of stunning. Alternatively, or in addition, an assessor can stand still at a single point along a shackle line and perform certain checks on consecutive birds that pass by; however, at fast line speeds this typically only allows time to perform one type of assessment per bird and it may be difficult to assess whether a bird is rhythmically breathing.

Recovery of spontaneous breathing is considered to be the earliest indication of recovery of consciousness (EFSA, 2013c). The presence of rhythmic breathing indicates an animal is alive, but not necessarily conscious and is therefore, technically, not a good indicator of the state of sensibility (EFSA, 2012). Nevertheless, it remains a useful assessment tool because if a bird is breathing, then it has the potential to recover consciousness (Prinz *et al*, 2012). For example:

- If a bird is rhythmically breathing immediately after exiting a waterbath, then:
 - it has either avoided the electrified water or,
 - if its head was immersed in the electrified water, the waterbath is malfunctioning or the electrical parameters are clearly ineffective and the current amplitude is most likely far lower than recommended for bird welfare.
- If a bird is not rhythmically breathing immediately after its head is withdrawn from the water, but it begins rhythmically breathing at some point during bleeding, then it has survived the treatment and the stun can be considered ineffective because it may not provide a sufficient duration of apnoea (and perhaps unconsciousness), during which death can occur by bleeding. The electrical parameters and the timeliness and quality of neck cutting must be investigated to determine why birds are not dying and why they might be regaining brain function.

A humane back-up stunning method should be immediately applied to any breathing birds.

EFSA (2013a,c) suggests the presence of regular gagging (a brainstem reflex of forced/laboured breathing through the mouth) may gradually lead to resumption of rhythmic breathing, so any bird displaying gagging behaviour should continue to be observed and action taken if necessary.

Death can be ascertained by testing for the absence of a **nictitating membrane** (third eyelid) reflex or by testing for the absence of a corneal reflex (Gregory 1989 in Prinz, 2009; EFSA, 2012), as shown in Figure 29B. Although a positive reflex indicates a bird



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is alive, it does not necessarily indicate that the bird is conscious. However, the proportion of birds displaying eye reflexes (eg nictitating membrane reflex and **palpebral reflex**), either at certain times or over a specified time, can be useful for monitoring the effectiveness of an electrical stunning system. For example:

- A stun may be ineffective if:
 - the corneal reflex can be repeatedly elicited immediately after a bird exits the electrified water (von Wenzlawowicz & von Holleben, 2001), or;
 - a large proportion of birds display a positive reflex (Prinz, 2009).
- Assess birds for eye reflexes at multiple points on the shackle line, eg:
 - immediately after exiting the water but before neck cutting and then at 15, 30 and 60 seconds after exiting the water;
 - as the time increases since exiting the water, if there is an increase in the proportion of tested birds displaying a positive reflex, it suggests the return of some brain function and the possibility that consciousness may also be able to return (Prinz, 2009). The whole slaughter system, and in particular the electrical parameters and the quality of neck cutting, must be investigated to determine why birds might be regaining brain function. A humane back-up stunning method should be applied to those birds immediately.



Indications that a bird has not been stunned or that it may be recovering from a stun (ineffective stunning):

- Presence/return of rhythmic breathing - examine a bird's abdomen (Figure 29Ai) for evenly-spaced rise-and-fall movements indicating inspiration and expiration. (Do not confuse with localised, rhythmic contractions specifically of the **cloaca** (Figure 29Aii).)
- Presence of a corneal reflex (Figure 29Bv) or a nictitating membrane reflex (Figure 29Bi-iv), particularly if a positive result is highly repeatable.
- Presence of a palpebral, or blink, reflex (the upper and lower eyelids meet to close the eye (Figure 29Bv) when the corner of the eye nearest the beak (medial/inner palpebral commissure/canthus) is gently touched).
- Presence of a pupillary light reflex (the pupil constricts in response to a bright light shone close to the eye).
- Presence of regular spontaneous eye blinking (ie blinking without human stimulation), particularly if the frequency increases with time (Prinz, 2009). (Not to be confused with very rapid blinking that may terminate abruptly after a few seconds in a bird that is not breathing. These may be muscular **fibrillations** of the eyelid, not an indicator of recovery (Prinz, 2009).)
- Presence/return of muscle tone, eg a bird regains voluntary control of its neck and head. (Note: some electrical parameters may cause an involuntarily arched neck, which can be an indicator of effective stunning (Figure 29Aiii). The difference can be ascertained by placing a hand under the bird's upper neck and head, and gently and repeatedly lifting them; if the bird holds its head away from the hand, or if the neck feels tense, it is likely to be recovering (Gregory & Wotton, 1990). Alternatively, an assessor can grasp the head of a shackled bird and gently pull it downwards; if the bird recoils it is probably conscious (N. Gregory pers. comm. 2014).)
- Presence of voluntarily-controlled vocalisations.



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Indications that a bird may be effectively stunned (but not killed):

- No rhythmic breathing (examine the bird's abdomen).
- Absence of a corneal reflex or absence of a nictitating membrane reflex. (Note: the presence of these reflexes indicates a bird is alive but not necessarily that it is conscious - additional checks for consciousness should be performed immediately.)
- Absence of spontaneous eye blinking of the nictitating membrane or outer eyelids (may suggest a deep level of unconsciousness).
- A lack of intrinsic (voluntary) control of muscles, eg a relaxed jaw with no muscular tension controlling movement of the beak; a relaxed neck with no self-controlled movement of the head.
- Constant rapid body tremors.
- Wings held tightly against body.

Indications that a bird may be dying, or has died, as a result of the electrical stun:

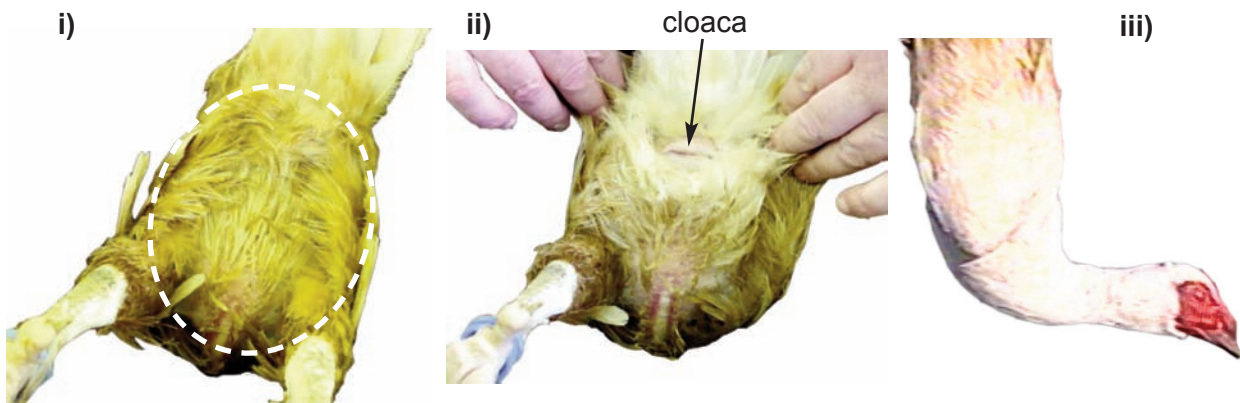
- No return of rhythmic breathing; no gagging (EFSA, 2013a).
- Absence of a corneal reflex and absence of a nictitating membrane reflex.
- Absence of spontaneous eye blinking.
- Pupils dilated and centrally-fixed.
- Relaxed, limp body with no pulse, no muscle tone, no movement; wings drooping.



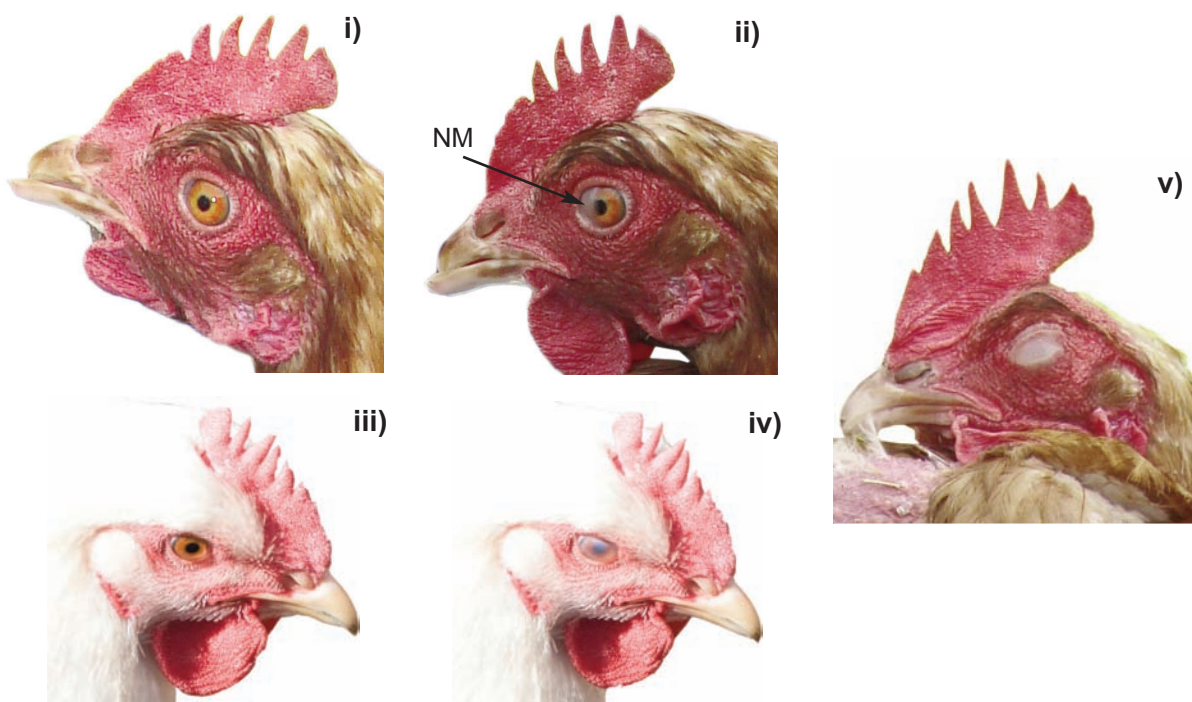
Assessing effective stunning

Figure 29. Assessing poultry behaviour to determine the effectiveness of stunning.

A) Rhythmic breathing and neck tension. i) chicken restrained in an inverted position, with the observer looking down upon it. The whole abdomen (encircled), should be examined for rhythmic rise-and-fall movements that might indicate respiration and therefore recovery; ii) with the feathers parted, the cloaca (vent) is visible. The cloaca may rhythmically contract inwards and outwards on its own, without abdominal respiration, and is not thought to be a sign of recovery; iii) after electrical stunning, this inverted duck is displaying an involuntarily arched neck, held parallel to the ground, with the head hanging down vertically; this may be an indicator of effective stunning.



B) Eye reflexes. If a bird is alive when its cornea (the surface of the eyeball) is gently touched, either the upper and lower eyelids will move to touch one another, to close the eye (a positive corneal reflex - image v); or the nictitating membrane will rapidly move across and over the cornea, to cover it briefly, before retracting back out-of-sight (a positive nictitating membrane reflex). Images i-iv) show the nictitating membrane reflex in conscious birds; it will look the same when a bird is assessed in an abattoir. i) & iii) The egg-laying and broiler chickens' nictitating membranes are currently hidden from view; ii) the hen's nictitating membrane (NM) has commenced passage across the eye; iv) the broiler's nictitating membrane has passed across the entire surface of the eye, giving it a 'cloudy' appearance.





Exsanguination

Neck cutting is the final step of the slaughter process. Its purpose is to bring about bleeding and the death of a stunned bird. Even if the intention is to use electrical parameters that will cause the majority of birds to die in a waterbath, it may be unlikely that 100% of birds will experience cardiac arrest, particularly if using current amplitudes lower than those in Table 6 and/or if using a constant voltage stunner. Consequently, any surviving birds are reliant on a follow-up killing method (ie neck cutting) being performed thoroughly and quickly, to prevent recovery of consciousness. Therefore, birds should not be passed through an electrical waterbath unless they can be immediately checked for effective stunning and then immediately bled. Only after a bird has been checked and confirmed to be effectively stunned, should its neck be cut.

The blood loss must be rapid and profuse in order to achieve a quick death. Ideally, the cut must sever all the major blood vessels in the neck of a bird (EFSA, 2004), particularly those that supply oxygenated blood to the brain, the most important of which are the two common carotid arteries. By preventing oxygenated blood from reaching the brain, ischaemia will set in and the brain cells will die, preventing recovery of consciousness. Ideally, slaughterpersons should also sever the two jugular veins, even though they carry deoxygenated blood away from the brain (Table 8).

Time to irreversible unconsciousness and time to brain death

There must be insufficient time for recovery of consciousness, before permanent loss of brain function due to lack of oxygen. Table 8 shows the time taken for poultry to lose brain activity, depending on which blood vessels are severed. Following electrical stunning of broiler chickens, severing both common carotid arteries and both jugular veins will achieve a quiescent EEG (a sign of continuing effective stunning) within approximately 15 – 30 seconds (Raj *et al*, 2006a,c). This is quicker than after severing only one carotid artery and one jugular vein, which in some cases can take 1 – 2 minutes to achieve a quiescent EEG, particularly as the frequency of the current increases (Raj *et al*, 2006a,c). Compared to severing only one carotid artery and one jugular vein, severing both carotid arteries and both jugular veins will also reduce the proportion of birds displaying behavioural indicators of consciousness (Raj *et al*, 2006a,c). (Note: although severance of both carotid arteries is a rapid means of bleeding a bird, it cannot be used to compensate for inappropriate electrical parameters, eg those that do not provide a sufficient duration of unconsciousness.)

In Europe, if waterbaths operate at ≥ 51 Hz, both carotid arteries, or the vessels from which they arise, shall be systematically severed (EC Regulation 1099/2009). Whatever stunning parameters are used, good practice for animal welfare and meat quality is to immediately sever both carotid arteries and both jugular veins as an absolute minimum, in all birds. This policy may reduce the risk of recovery of consciousness for any birds that are temporarily stunned (including because if variation in resistance causes some birds not to receive a high-enough current amplitude to cause death, even if the abattoir intends so).



Table 8. A comparison of the relative speed at which cardiac arrest and different types of neck cut can cause poultry to die (Gregory & Wotton, 1986, 1988b).

Severing both carotid arteries and both jugular veins produces a rapid rate of blood loss and the quickest time to death of all the exsanguination methods. For chickens and ducks, induction of cardiac arrest is the only method that is quicker. For turkeys, severance of both carotid arteries and both jugular veins may ensure a faster death than cardiac arrest (Gregory & Wotton, 1988b). For all species, severing both carotid arteries is critical; if one or both are left intact, brain death is delayed.

[The values shown are the times to loss of at least 95% of visual evoked responses (VERs). (SE = standard error.) The loss of spontaneous and evoked brain activity indicates brain failure ($\geq 95\%$ of spontaneous brain activity was lost earlier, or at a similar time, to loss of $\geq 95\%$ of VERs). The values do not indicate the time to irreversible unconsciousness, which will occur earlier.]

Treatment (eg vessels cut)	Average time (seconds \pm SE) to < 5% of pre-cut VERs (Specific method of cut described where necessary)		
	Chickens	Ducks	Turkeys
Cardiac arrest	90 \pm 8	115 \pm 7	90 \pm 3
Both carotid arteries & both jugular veins	136 \pm 16 (decapitation)	172 \pm 28	--
Both carotid arteries	163 \pm 11	--	64 \pm 5
One carotid artery & one jugular vein	302 \pm 30	--	--
Both jugular veins	332 \pm 23	--	--
One jugular vein	349 \pm 22	332 \pm 21 (mouth or beak cut)	--
Jugular vein anastomosis	--		--

Locating and identifying the carotid arteries and jugular veins

The carotid arteries lie embedded in the muscle of the neck but, depending on the species of poultry, they vary in how close they lie to the cervical vertebrae (the neck bones). In chickens, geese and guinea fowl, near the head, the arteries are typically visible on the surface of the muscle (Figure 30b). Whereas in turkeys, the arteries remain hidden underneath the surface of the muscle, even near the bird's head (Figure 30c). Ducks have very deeply embedded arteries and these cannot be seen from the surface of intact neck muscle. In all species, the carotid arteries are most easily accessible for cutting from the ventral aspect (underside) of the neck, ie the throat.



Figure 30a. Schematic of a bird's head and throat, with the ventral (lower) jaw, trachea and oesophagus removed, to show the position of the common carotid arteries and external jugular veins and the ideal location to perform a ventral neck cut to sever all four major blood vessels.

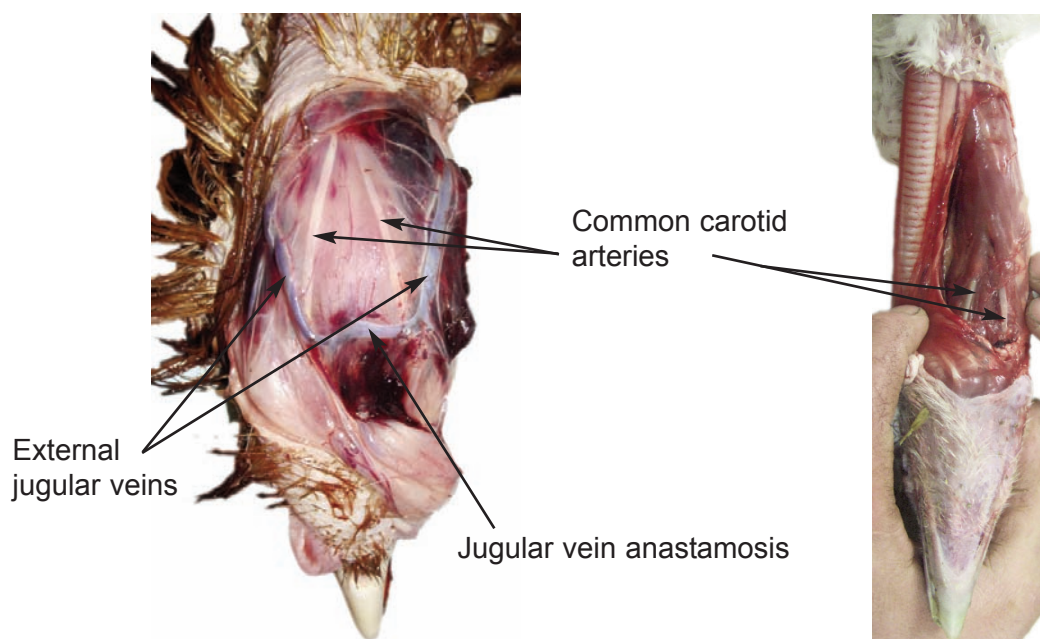
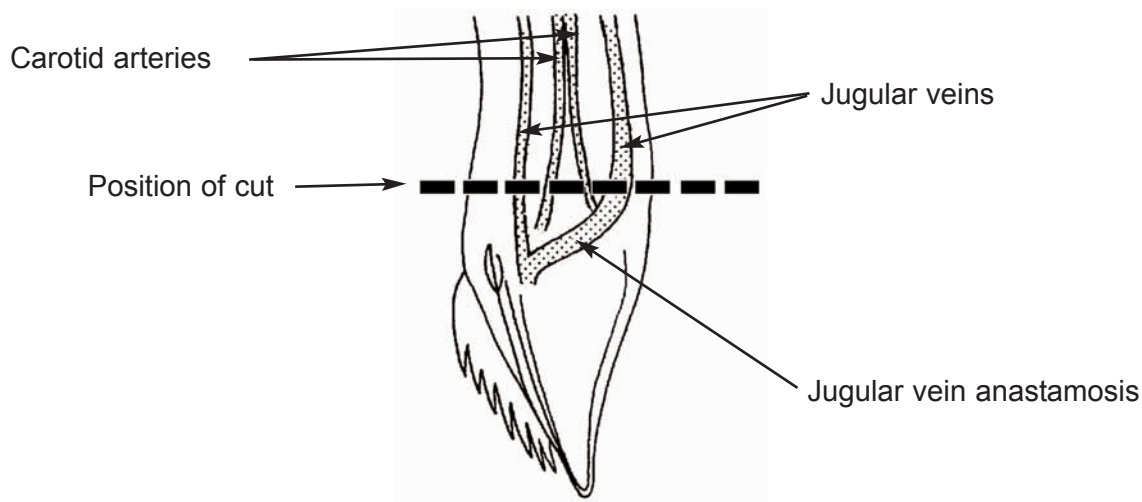


Figure 30b. Dissected throat of an end-of-lay chicken, to show the major blood vessels. The external jugular veins lie just under the skin and have thin walls so blood can be seen within them. The carotid arteries are in the neck muscle and have thick walls so the blood inside cannot be seen. (The oesophagus and trachea cannot be seen because they are pulled round, underneath the bird for the purpose of the photograph.)

Figure 30c. Dissected throat of a turkey to show the carotid arteries (white tubes) embedded within the neck muscle. The muscle has been cut to expose the arteries. (The jugular veins cannot be seen because the skin is folded underneath the bird for the purpose of the photograph.)



Performing an effective manual neck cut

Abattoirs may decapitate unconscious birds if they wish to be certain both carotid arteries and both jugular veins are severed. Decapitation is the preferred bleeding method if a shackle line becomes inaccessible after neck cutting, because once a bird's brain (head) becomes detached from its body, operators do not need to be concerned for the welfare of the body. After decapitation, immediate mechanical maceration of the head will ensure a rapid brain death.

If decapitation is not the preferred method of bleeding, then operators must perform a deep, transverse cut across the throat, close to the head. This is called a complete ventral neck cut (VNC) (Figure 30a) and is a very successful way to achieve severance of both common carotid arteries and both external jugular veins. Two methods of performing a manual ventral neck cut, depending on how much time is available to the slaughterperson, are described below. Both methods are suitable for any species of poultry, although Method A may be particularly suitable for larger birds such as turkeys (it may make it easier to sever their carotid arteries which lie deep within the neck muscle). Assuming you are the slaughterperson:

Method A:

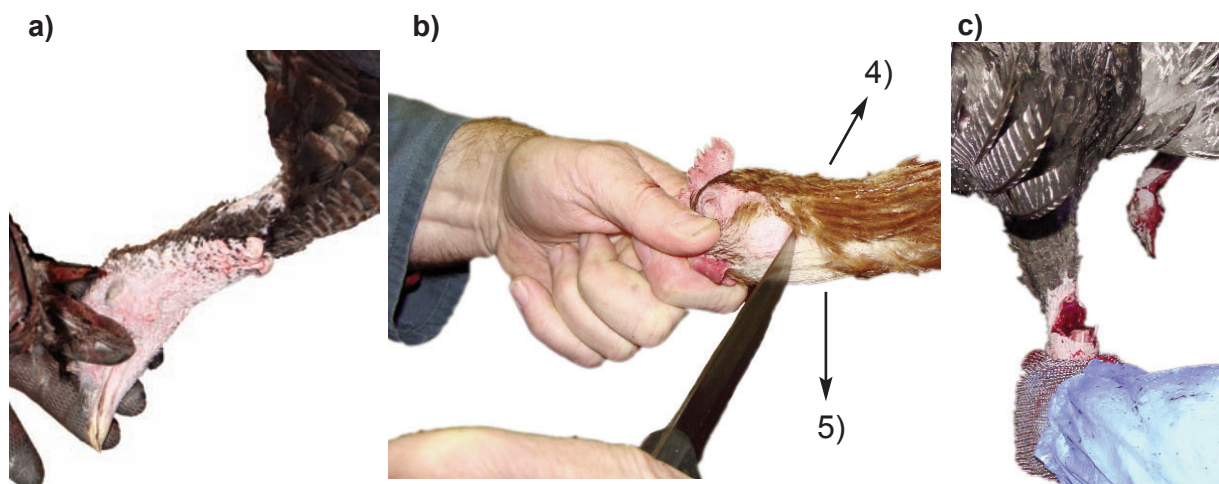
- 1) Hold the back/top of a bird's head in your palm, with your thumb and fingers positioned either side of the bird's head, over the cheeks (Figure 31a). This allows for a safe, firm grip and enough resistance for the knife to easily penetrate the neck.
- 2) Turn the bird's head so the side of the head and neck are facing you.
- 3) With the knife pointing away from you, and with the blade facing the same direction that the bird's throat is facing, position the point of the knife at the junction of the head and neck (ie just below the jaw bone) and slightly towards the ventral side of the middle of the bird's neck so the knife is in between the vertebrae and the trachea (thereby avoiding the vertebrae) (Figure 31b).
- 4) Then push the knife into the middle of the neck and straight through and out the other side of the neck (as if performing a spear-stick cut) (Figure 31b).
- 5) Then, with the knife in the same position, pull the blade through the tissues of the throat to open the throat completely (Figure 31b).
- 6) If you are unsure whether both carotid arteries are severed, you should immediately turn the blade around so it is facing towards the bird and carefully cut back into the wound, up to (but not into) the vertebrae. It is important to manoeuvre the blade to also cut both sides of the throat, to ensure no blood vessels escape the knife.

Method B:

- 1) Firmly hold the beak and rostral part of the bird's head, ensuring your fingers are not within the trajectory of the knife. It is important to maintain a firm grip, to provide resistance for the knife to work against.
- 2) With the bird's throat facing you, position the blade on the throat, at the head-neck junction and on one side of the bird's neck.
- 3) Press the blade onto the throat and, whilst applying pressure, pull the knife across the throat and round to the other side of the bird's neck, in one smooth, uninterrupted action. (Cutting the sides of the throat in this manner (Figure 31c), may allow the knife to 'follow' and cut the muscle and blood vessels, if they are pushed to the side by the movement of the knife.)



Figure 31. How to manually restrain a bird's head and apply a ventral neck cut. Restrain the head using any of the grasps shown. b) relates to Method A: 4) push the knife through the middle of the neck in a straight line so it emerges out the other side; 5) then pull the knife through the tissues of the throat. Whichever of the suggested methods is used, after cutting, the throat should look like that of the bird held in c): the neck muscle and sides of the throat are visibly cut. (Consider wearing suitable personal protective equipment, eg chain mail glove.)



Immediately after performing the neck cut, the slaughterperson must look for two thin 'jets' of blood spraying under high pressure (Figure 32) – this indicates both common carotid arteries have been severed. Slow-flowing or dripping blood immediately after cutting may indicate the jugular veins are cut but the carotid arteries may still be intact so the bird should be cut again. No, or very limited, blood flow after cutting also suggests an ineffective cut, even in small species, eg quail; immediately perform the cut again, until sufficient blood flows.

Figure 32. A stunned turkey that has received a ventral neck cut. The turkey's two common carotid arteries have been successfully severed, as indicated by the upside-down V-shaped pattern of blood flowing from the arteries which are embedded within the neck muscle. The high-pressure arterial flow typically subsides five to 10 seconds after neck cutting.

It should be simple for slaughterpersons to self-check their neck cutting efficacy by checking that each bird displays this pattern of high-pressure blood-loss.

Limited, or only dripping, blood flow may suggest the carotid arteries remain intact and the cut should be immediately performed again to prevent any possibility of recovery.





All manual slaughterpersons must be trained and competent at accurately administering a neck cut, especially at fast line speeds. The success rate in severing both carotid arteries can vary between slaughterpersons working at the same site (Gregory & Wotton, 1986).

Automated mechanical neck cutters

European Regulation 1099/2009 requires that birds shall not be slaughtered by ANCs unless it can be ascertained whether or not they have effectively severed both blood vessels [carotid arteries]; when ANCs are ineffective the bird shall be slaughtered immediately by another means.

Automated mechanical neck cutters (ANCs) can be set-up to deliver a ventral neck cut, but it is essential that every bird is presented to the blade(s) in the correct orientation, otherwise the carotid arteries may be missed. A guide rail system should accurately position a bird's throat against the rotating blade(s) to cut very close to the head-neck junction, and to a sufficient depth to penetrate the muscle and sever both common carotid arteries. ANCs can have two blades, which can be set up so a bird's neck passes between them (Raj, 2004); this may produce a bilateral neck cut which is acceptable if both common carotid arteries and both external jugular veins are severed. ANCs must not be set up to deliver a dorsal neck cut because a) this may miss both common carotid arteries and result in a slow bleed-out (Gregory & Wilkins, 1989c), and b) it may damage the spinal cord and prevent further assessment of the effectiveness of stunning (Gregory & Wotton, 1986). Therefore, ideally, the spinal cord should not be severed. However, the priority is to sever both carotid arteries and if this outcome can only be reliably achieved in conjunction with some damage to the spinal cord, then this is acceptable and the more appropriate choice for animal welfare. The height of an ANC must be adjustable in order to suit each batch and type of bird processed, so all birds are cut in the correct anatomical position (EFSA, 2004).

Stun-to-cut time

Once confirmed unconscious, birds must have their necks cut immediately and, at the latest, within 15 seconds of stunning at 50 Hz and within 10 seconds of stunning at higher frequencies (Defra, 2007). If the primary means of neck cutting is manual, every slaughterperson must be positioned within 10 – 15 seconds of the exit from the electrified water (the actual distance will vary with the line speed), including the last slaughterperson in the team. The line speed must allow employees to work at a pace that ensures a high quality of neck cut. If slaughter personnel cannot routinely sever both carotid arteries and both jugular veins, then there must be a re-evaluation of the system, including whether the line speed is too fast for the number of operators working at this point or if staff need re-training.

If the primary means of neck cutting is an ANC, it must be capable of keeping up with the line speed, so birds are cut as quickly as possible and do not build-up at the entrance to the ANC, and/or bypass it. There must be a manual slaughterperson positioned immediately after the ANC, to cut any stunned birds that either completely miss the ANC or receive an insufficient cut from it. The ANC *and* the slaughterperson must both be able to perform their cuts within 10 – 15 seconds of the birds exiting the electrified water.



Delayed and/or inadequate neck cutting can cause a slow rate of bleeding (eg Table 8) and retention of blood in engorged vessels in the wing, breast and thigh muscles, which further processing (eg plucking) may worsen by rupturing those vessels and massaging the blood into the surrounding tissue, creating red wing tips for example (Gregory & Wilkins, 1989b; M. Raj, pers. comm. 2014). It is therefore important for abattoirs to perform comprehensive neck cuts and to maximise the bleed-out time before further processing.

Monitoring birds as they bleed-out on a shackle line

After a neck cut is administered, if a bird's head remains attached to its body:

- Each bird must be checked for effective neck cutting and bleeding.
- Birds must be checked for continuing unconsciousness until death is confirmed.
- Birds must not be electrically stimulated or further processed in any way (eg plucked or scalded) until death is confirmed.

Following stunning, if a bird displays relatively greater amounts of convulsions (compared to other birds on that slaughterline), it may indicate the bird has not experienced cardiac arrest, and/or that it received a poor quality neck cut (and therefore has sustained a supply of oxygenated blood to nerves and muscles). Such birds must be examined for the quality of neck cutting and the effectiveness of stunning.

Before further processing, birds should be left to bleed for a sufficient time. Table 8 displays the times to brain death, depending on which method of killing is used. In addition to achieving death, bleed-out durations of 2.25 – 3 minutes were found to be better for meat quality and produced equivalent bleed-out in birds that experienced cardiac arrest and those that did not (Schütt-Abraham *et al*, 1983; Heath, 1984; Gregory & Wilkins, 1989c).

For every slaughterperson and ANC employed, an AWO must frequently examine birds' neck cuts (after death and before further processing) to determine which blood vessels are severed. If the common carotid arteries are not consistently severed in, ideally, 100% of birds, there must be a re-evaluation of the neck cutting procedure and either a slaughterperson may need retraining, an ANC may need adjusting, the cutting method must be improved or a more suitable method of cutting must be employed. Types of neck cut that are likely to have difficulty severing both common carotid arteries are listed below. (With these methods, it is also likely that the AWO will need to dissect the neck of each bird that is sampled, to view which blood vessels have been cut; this is time-consuming and may be considered to prevent easy and rapid assessment of the effectiveness of neck cutting.)

- Dorsal neck cuts. Unlikely to sever the carotid arteries, which are located on the ventral side of the vertebrae (Gregory & Wotton, 1986).
- Unilateral cuts to one side of the neck only. Typically only severs one jugular vein and sometimes one carotid artery (Gregory & Wotton, 1986; Raj *et al*, 2006a,b,c).
- Spear-stick cuts are made by pushing a thin knife through the middle of the neck



Maintenance of equipment

and withdrawing the knife through the same wound, without further manipulation of the knife inside the neck. Inconsistently severs both carotid arteries (Gregory & Wotton, 1986).

- Mouth or beak cuts (known as *per os*); a knife is inserted into the mouth and into the throat where the cut is made, near the base of the skull. Typically only severs the jugular vein anastomosis or one jugular vein (Gregory & Wotton, 1986).

If a bird appears to be recovering, it must be stunned and killed immediately using a humane back-up method, eg a captive-bolt device designed for poultry. Therefore, shackle lines must be designed to allow personnel to immediately and easily tend to any bird, anywhere on the line, without endangering themselves. For example:

- A shackle line that winds back on itself must be designed in a manner that allows personnel to immediately access birds *anywhere* on the line.
- Blood-collection troughs must not obstruct a person from removing a bird from a shackle or force the person to make an awkward manoeuvre (Raj, 2004).

Maintenance of knives and automated mechanical neck cutters

Neck cutting should always be carried out using a sharp clean knife with a blade that is at least 12 cm long. Although a sharp knife might be considered dangerous, correct use of one may allow more precise cuts to be performed more quickly and therefore ensure birds are bled efficiently and safely. Blunt knives may lead to premature cessation of blood flow (Bilgili, 1992).

At the start and end of each processing shift, all blades and knives should be inspected for damage and sharpened whenever necessary to ensure consistent, effective and rapid cutting. ANCs must be checked daily by the AWO to ensure the equipment is set correctly and working effectively.

Blades must be cleaned thoroughly to maintain their operational efficiency. A knife cleaning/sharpening station must be positioned immediately adjacent to, or in front of, the position where a slaughterperson stands when cutting birds. This should allow the slaughterperson to clean/sharpen the knife without changing position and to keep track of birds yet to be cut (or checked for effective cutting), giving the slaughterperson more time to catch up.

General maintenance and monitoring of equipment

Equipment for moving, handling, restraining, stunning and killing poultry, including any back-up equipment, must be designed, manufactured and maintained to ensure consistent, effective handling, stunning and killing, so that all birds are physically comfortable, immediately stunned and remain unconscious during the process of dying.

Stunning and killing equipment is potentially hazardous to personnel operating it. The safety procedures detailed in manufacturers' manuals must be strictly adhered to. All companies should have standard operating procedures (SOPs) for the regular maintenance activities (eg calibration, cleaning), based on the instructions in the manufacturer's manual.



Maintenance of equipment

Each operator must be appropriately trained and skilled in the duties for which they are responsible. These might include some or all of the following: setting up, testing, operating, monitoring, calibrating, cleaning and repairing the restraining, stunning and killing systems. The nominated AWOs must ensure these procedures are routinely performed by the appropriate personnel before slaughter can commence.

All restraining, stunning or killing equipment must be checked and tested at the beginning and end of each day against clear pass/fail criteria, the results of which should be documented, as per the company SOPs. Records of routine inspections of equipment must be kept and be available for regular monitoring, to discern how equipment is performing over time. Records may also be required as part of an inspection by the veterinarian, food hygiene authority or others. During processing, equipment must be monitored to ensure it is in good working order and functioning appropriately, from the perspective of both animal welfare and human health and safety.

Every day, shackles, electrical stunners, back-up stunners and neck cutting equipment must be thoroughly cleaned and sanitised, inside and out, so any build-up of dirt, grease, fat, scale and carbon is removed. Cleaning and repairs should be carried out when equipment is turned off, but should still be done with extreme care, without removing or blocking safety devices.

Care must always be taken to ensure switches, dials and other parts of devices are not blocked or altered as a result of any procedure, eg cleaning or calibrating. For example, house the control panel of an electric stunner in a suitable, transparent, protective (waterproof) box through which the meters can still be read. Personnel can automatically be informed, via indicator lights on the equipment, of the status of the equipment, eg 'voltage on', 'voltage off'. If alterations are made, the equipment must be returned to its original setting immediately afterwards. Whether an alteration was intentional or accidental, all alterations must be reported to personnel with the authority to assess, and if necessary reset, the equipment before slaughter commences.

A sufficient number of humane back-up stunning devices, suitable for use on the species of poultry being processed, must be stored at the restraining, stunning and bleeding points and must be readily accessible in the event of an emergency or a line breakdown. The condition of all components of a back-up stunner must be thoroughly checked on a daily basis and recorded. For captive-bolt stunners, particular attention must be given to the condition of the bolt, recuperator sleeves, washers and the breech. Cartridge-powered models must have any carbon and silica deposits removed during cleaning, otherwise the carbon and silica will harden over 24 – 48 hours, which might prevent the bolt from discharging effectively and to its full extent, leading to a reduction in its power. Even if a device is fired only once, good practice is to thoroughly clean it on completion of slaughter for that working day.



Humane slaughter checklist

A successful electrical waterbath slaughtering system is dependent on the following:

- Correct set-up of all equipment.
- Regular inspection, testing, calibration and maintenance of all components in the slaughter system, eg regularly clean electrodes and shackles with acid and wire brushes and check that no current flows when birds are not immersed in the electrified water.
- Fully trained, competent and compassionate lairage staff and slaughterpersons.
- Minimising fear, stress, discomfort and pain of birds during handling and shackling.
- Shackles must be dripping wet before birds are hung into them; this should enhance conductivity during stunning and may reduce frictional forces during shackling.
- Shackling birds for as short-a-time as possible.
- Use a breast contact strip or support conveyor that maintains contact with each bird's breast throughout the duration of time the birds are shackled and conscious.
- A shackle line must be straight whilst the birds are conscious.
- Shackled conscious birds should be sufficiently spaced apart to prevent physical contact whilst in the waterbath; this may limit the variation in the current amplitudes received in a constant voltage stunner (Sparrey *et al*, 1992).
- Encouraging as many birds as possible to adopt an ideal posture for entry to a waterbath. Good entries may be seen in birds that hold their neck extended towards the floor, their head down and their wings folded into the closed position against the body. To assist, shacklers may need to gently fold a bird's wings into the closed position, whether the birds are against a breast contact strip or on a breast support conveyor. With closed wings, birds may be less likely to touch one another in the waterbath.
- Slaughtering birds in batches in which the individuals are as uniform as possible. This should allow more efficient and humane stunning in terms of reduced compression of some birds' legs, better entries to the electrified water and more similar current amplitudes when using a constant voltage stunner.
 - Avoid shackling together birds that are different in size (including length, leg circumference), age or expected body fat and muscle content. For example, slaughter males and females separately.
 - Runts or very small birds must not be shackled for waterbath stunning because they may miss the electrified water and/or miss an automated mechanical neck cutter. They must be slaughtered using an alternative humane stunning method.
- Prevention of pre-stun electrical shocks.
- A waterbath should be of an adequate size (particularly width and depth) for the type of bird being slaughtered. Undersized, or even oversized, individuals must not be shackled for waterbath stunning if their size puts them at risk of ineffective stunning



Humane slaughter checklist

- Monitoring the position of birds in the electrified water to increase the likelihood that sufficient current will flow through the target organ(s), ie the brain (and heart in the case of intended stun-killing) (EFSA, 2004).
 - The water level in a waterbath must completely cover the entire head of each bird (including the cranium of the smallest bird suspended) and, if necessary (eg in Europe), the neck and up to the rostral edges of the wings (ie shoulders).
- The submerged electrode must span the entire length and width of a stunner and the earthed rubbing bar(s) electrode must span the entire length of a stunner.
- Continuous physical contact between the components of an electrical circuit, throughout the intended duration of current flow, ie from the electrode/water to the bird's head, the bird's legs to the shackle and occupied shackles to the earthed rubbing bar(s). This should allow for receipt of a consistent amplitude of current.
- The good condition of all components that enable current flow. Replace if worn or damaged, or if scale or carbon residues are present and if descaler and acid are ineffective at removing the scale or residues. (Scale and carbon residues can impede current flow, even though there is physical contact.) Keeping resistance as low as possible at all conduction points between the birds and the electrodes may avoid the need to use excessive voltages to reach the required current (Schütt-Abraham & Wormuth, 1991).
- Selection of equipment capable of delivering electrical parameters appropriate for animal welfare.
 - The latency to deliver the recommended current may vary with the available and applied voltage (EFSA, 2004). Electrical waterbaths must be supplied with an appropriate input voltage, to ensure stipulated currents are reached and birds become unconscious immediately.
 - It is necessary to program a constant voltage stunner to deliver a minimum voltage that is capable of delivering the recommended current to 100% of birds (EFSA, 2004). When under load, the ammeter on the stunner control panel must display a total current that equals, or exceeds, the number of birds simultaneously in the water multiplied by the minimum recommended current per bird (EFSA, 2004). If birds are stunned in mixed-sex batches, abattoirs must use a voltage sufficient to ensure all sexes receive the minimum recommended current amplitude. Alternatively, if necessary and if practical, separately slaughter males and females (eg broiler chickens) in order to provide females with the necessary higher voltage and to limit any damage to the carcasses of males.
 - If, in future, a true constant current stunner becomes available, it is likely to be preferable to use that type of stunner because it should be able to control the delivery of a constant current to each individual bird. This should be irrespective of the number of birds in contact with the water, any differences in resistance attributable to species, breed, strain, sex and age of bird, as well as the electrical waveform, all of which are otherwise difficult to predict and control for.
- Choose electrical parameters that should ensure 100% of birds are immediately stunned and remain so until death occurs.
 - Apply a current that at least meets, or exceeds, the threshold amplitude recommended to induce generalised epileptiform activity (EFSA, 2006) followed by a quiescent EEG (EFSA, 2004).
 - Sine AC may provide a more effective stun than other AC and pDC waveforms.



Humane slaughter checklist

- Monitoring equipment to ensure it actually delivers electrical parameters as appropriate for the welfare of each type of bird. Use the waterbath control panel ammeter and remote stun monitors to check that current is applied for a sufficient duration, not exceeding the recommended maximum frequency or using less than the recommended minimum amplitude of current.
- Installation of slaughter systems in a layout that allows personnel to safely and easily assess and access birds at any point on a shackle line, from shackling to entry to a scald tank. If access is denied because personnel are obstructed by features of the system or other equipment, eg if fast line speeds or the height of a shackle line effectively puts the birds out of reach, then the system should be redesigned. Use equipment that enables operators to access birds quickly in emergencies (eg Figure 33). Emergency access points should be designed to enable staff to a) easily perform emergency back-up stun/killing operations on the shackled birds (ie birds' heads and necks must be sufficiently accessible) and b) to easily remove birds from their shackles, if necessary.
- Construction of shackle lines in a layout that enables birds to be checked for effective stunning before their necks are cut.
- Recognition of an ineffective stun.
- Birds must not be passed through a waterbath until a slaughterperson or ANC is ready and waiting to cut the birds.
- Accurate, consistent severing of at least both common carotid arteries and both external jugular veins, as soon as possible and within 10 seconds of high frequency stunning and 15 seconds of 'standard' frequency (eg 50 Hz) stunning.
 - For all species, it is necessary to cut into the neck muscle, to sever the carotids.
 - A ventral neck cut is an effective means of reliably severing both carotid arteries and therefore for bleeding birds as much, and as quickly, as possible, thereby protecting their welfare and benefitting meat quality.
 - Sufficient time for a bird to bleed out. (Incomplete bleeding may lead to downgrading of breast fillets and red wing tips.)
- Recognition of an ineffective neck cut. If an operator is unsure if the carotid arteries are cut, they must cut the bird again.
- Rehearsed contingency plans. For example, if power to a waterbath fails:
 - The shackle line must automatically stop to prevent conscious birds' heads being immersed in non-electrified water.
 - Birds that have already received an electric current and are unconscious must receive a ventral neck cut immediately, to prevent recovery.
 - Birds that received an electric current and are showing signs of recovery must be re-stunned using a back-up method and then bled.
- Immediate availability of a sufficient number of humane back-up stunning devices.
- Clear standard operating procedures. For example, if there is any indication that restraint, stunning or killing equipment is not operating effectively, slaughter must cease until the system is checked and any faults are corrected. An electrician or

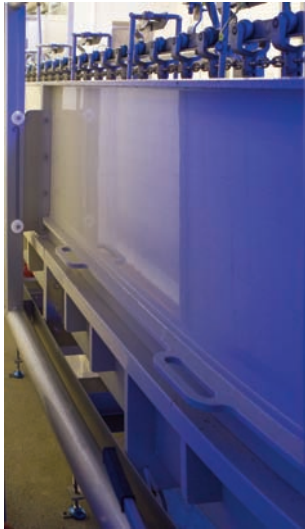


Humane slaughter checklist

electrical engineer must be on-site and on-call during slaughter, in order to respond quickly and effectively to equipment failures.

Figure 33. A waterbath with vertically sliding panels along its length, to enable staff to access birds within the waterbath in an emergency. The left image illustrates the waterbath during operation with the panel closed and the right image shows the raised panel.

Images: Marel Stork Poultry Processing.





Animal welfare policy, SOPs

Animal welfare policy, standard operating procedures and contingency plans

All abattoirs slaughtering live animals should have a written animal welfare policy (AWP). The policy should detail the species, sexes and ages of birds that the site is equipped to accept. An AWP should incorporate guidance measures to help personnel comply with legislation and customer requirements (eg assurance schemes or retailer standards). An AWP must refer to:

- written standard operating procedures (SOPs) for setting-up, operating (including a list of the required key parameters), calibrating, cleaning and maintaining equipment, eg read Appendices I and II. (SOPs are a legal requirement in Europe (EC Regulation, 1099/2009).);
- written contingency plans, which must be readily-available at all times, and rehearsed, so all operators and supervisors know exactly how to act if a piece of equipment fails, and/or in an emergency.

Companies must ensure all persons engaged in activities with live animals, or who work in the areas of the site where live animals are kept, are aware of, and fully-versed in, the provisions of the company AWP, the legislation and the relevant animal welfare codes of practice, alongside additional training on how to safeguard bird welfare at all times. An AWP is a useful tool for training new members of staff to work with live animals and for regularly updating the knowledge of existing staff.

An AWP must explain the procedure for personnel to communicate any welfare-related issues to a company Animal Welfare Officer (AWO) and/or to management. Within an AWP there should be a list of all trained AWOs working at the site and a copy of this list should be posted in the primary processing and/or lairage office. The name(s) of the on-duty AWO(s) for the current day/shift should be clearly written on a public notice board in the live animal area(s) so personnel are aware of to whom they should report welfare issues. AWOs can be made visible to personnel, eg by wearing a distinctive colour hard hat or overall.

Risk assessment and HACCP for animal welfare

Animal welfare should be considered, and SOPs written, in a manner that reflects the principles of a risk management system, eg Hazard Analysis Critical Control Points (HACCP). During each phase of a slaughter process (eg unloading, shackling, stunning), animals are exposed to **hazards** and run a **risk** of reduced welfare (SLU, 2009). Specific hazards may affect one or more components (eg fear, distress, pain, frustration) that collectively determine an animal's overall welfare. As well as performing a risk assessment of hazards to healthy animals that will be slaughtered in the routine manner, it is necessary to consider that, at the start of each phase, each animal will have a status that may vary relative to the status of other individuals and which will affect its susceptibility to hazards (SLU, 2009). For example, lame birds might have become injured on-farm, but may still suffer [disproportionately] at the abattoir, through shackling. A slaughter process should be flexible enough to accommodate these varying needs or should account for individual needs by applying separate slaughter procedures (SLU, 2009), eg lame birds should have their needs met by not being shackled for routine waterbath stunning, but by being humanely stunned using an alternative device such as a captive-bolt. Good stunning/killing practices (GSKP: SLU, 2009) that are based on risk assessment, must be adhered to, for HACCP to work. GSKPs might include much of the advice in these guidance



HACCP for animal welfare

notes, eg use key parameters appropriate for animal welfare. HACCP may allow for the reduction of hazards which, despite adhering to good practice advice, may still prevail to an extent (SLU, 2009), eg pre-stun shocks in waterbath stunners.

A properly executed HACCP plan is systematic, product-specific (eg bird type), hazard-specific (eg welfare hazard), process-specific (eg stunning/killing system) and enterprise-specific (eg site & kill line) (SLU, 2009). At each site, AWOs should collectively discuss (to draw on each other's relevant experiences) and perform the following procedures:

- **Conduct a hazard analysis:** to determine the hazards to animal welfare and how to control these hazards by identifying the preventative measures a HACCP plan can apply.
- **Determine Critical Control Points (CCPs):** these are points, steps or procedures during the stages of the slaughter process, at which control of the hazards can be applied to prevent, eliminate or reduce occurrence, in order to protect animal welfare. For example, read Table 9.
- **Establish critical limits for each CCP:** for example, the maximum and/or minimum value(s) to which a hazard must be controlled, to an acceptable level. Abattoirs must attempt to use validated critical limits, eg use scientific recommendations for critical limits.
- **Establish CCP monitoring requirements:** monitoring is necessary to ensure the process is indeed under control at each CCP. Each monitoring procedure and its frequency of monitoring should be listed in a HACCP plan.
- **Establish corrective actions:** when monitoring indicates a deviation from an established critical limit, these are the actions to be taken. These actions must be specified in a HACCP plan.
- **Establish procedures to verify that a HACCP plan is working as intended:** verification is intended to ensure that slaughter procedures are performed as they should be and that they are successful in protecting animal welfare. Abattoirs must validate their own HACCP plans.
- **Establish record keeping procedures:** all the above principles and associated protocols must be documented in written records to demonstrate they have been considered fully.

Managers with the appropriate technical knowledge, must regularly review (at least annually) the AWP, SOPs, contingency plans and HACCP plans (including CCP records and critical limits). In addition, they must be re-assessed in response to changes in legislation, customer requirements and technological and scientific developments. Whenever documentation is updated, it is vital that all amendments are relayed, verbally and in writing, to all personnel working with live animals.



HACCP for animal welfare

Table 9. Examples of Good Stunning/Killing Practices (GSKPs) from risk assessments and Critical Control Points (CCPs) for HACCP. (Adapted from SLU, 2009). Hazard identification involves listing factors that may possibly represent hazards to animal welfare. These may vary with slaughter systems and bird type. GSKP can then be devised, based on that factor's potential adverse effect on animal welfare. Where the hazard can be prevented, eliminated or reduced, CCPs can be introduced.

Hazards (from risk assessment)	Factor	GSKP (proper infrastructures, equipment or professional behaviour)	CCP (monitorable, correctable, verifiable and documentable)
<p><i>Phase: restraint</i></p> <p>Shackles</p>	<p>slots which are too-narrow or too-wide for the legs of a given bird type</p> <p>unclean, scaled or damaged shackles</p>	<p>use shackles that:</p> <p>a) have multi-gauge, tapering slots for birds' legs;</p> <p>b) are of an appropriate size for the bird type processed</p> <p>clean/repair/replace unfit shackles on-sight, eg remove and clean shackles that have scale or carbon residue; remove and repair/replace damaged shackles that have sharp edges, broken struts and worn ineffective contact points with the earthed rubbing bar</p>	<p>the proportion of birds with both legs shackled just after hang-on and just prior to entering the waterbath</p> <p>the proportion of birds with their legs in a sub-optimal position for stunning and why (eg shackle too loose or too tight; only toes held within shackle slot)</p> <p>the proportion of shackles returning to the live-bird shackling station with debris or severed feet retained in the shackles</p> <p>the proportion of shackles that are dripping wet on returning to the shackling station</p> <p>the frequency of cleaning of shackles with acid compared to the rate of build-up of scale and carbon on those shackles</p> <p>the number of damaged shackles, scaled-shackles and shackles with carbon-residue that are removed from service each week because they can no longer be used for live birds</p>
<p><i>Phase: stunning/killing</i></p> <p>Exsanguination</p>	<p>delayed neck cut</p> <p>ineffective neck cut</p>	<p>apply neck cut within 15 seconds</p> <p>cut both carotid arteries and both jugular veins</p>	<p>time bird reaches ANC and manual slaughterperson thereafter</p> <p>proportion of birds with both carotid arteries severed</p>



Animal welfare training

Animal welfare training

Companies must have documented, formal procedures for animal welfare training, in line with their AWP. Time and resources should be sufficiently allocated to annual animal welfare training, whether in-house or external. All personnel in contact with live animals must be taught basic concepts of animal behaviour and welfare and the reason for being sympathetic to the birds at this potentially stressful moment of their lives. Personnel involved in the handling, restraint, stunning and killing of birds must be given structured, documented training in their responsibilities for bird welfare. All live animal personnel should be fully aware of their duties and how to perform them effectively in order to optimise bird welfare. Personnel should be trained to perform certain procedures (eg cervical dislocation, captive-bolt stunning) on dead birds first (eg DOAs), to prevent any avoidable suffering for the animals and to increase the likelihood that trainees are relaxed during learning. Training all live animal personnel is critical to maximise their skill and efficiency, and therefore bird welfare. For all types of equipment relevant to an individual's job, operators should be fully trained:

- in how the equipment works and the inherent and potential welfare problems associated with its use;
- to identify signs of ineffective stunning and ineffective neck cutting;
- in the risks of, and how to avoid, injury from the animals, the restraining, stunning and killing equipment, eg if a person makes contact with the electrodes there is a danger of a fatal electric shock.

Staff training is a continuous process. All personnel should have their performance monitored and reviewed to ensure their needs are being met by the company and that each employee is meeting the needs of the birds. They must also be regularly engaged in discussion on animal welfare, and their views sought on potential ways to further improve bird welfare and the organisation of the system.

In Europe EC Regulation 1099/2009 decrees:

- *“Killing and related operations shall only be carried out by persons with the appropriate level of competence to do so without causing the animals any avoidable pain, distress or suffering”.*
- Business operators shall ensure that the following slaughter operations are only carried out by persons holding a Certificate of Competence (CoC), attesting the passing of an independent final examination and demonstrating a person's ability to carry out the operations in accordance with the rules in Regulation 1099/2009. A CoC must indicate which operations, which type of equipment and which categories of animal it is valid for. Operations include:
 - the handling and care of animals before they are restrained
 - the restraint of animals for the purpose of stunning or killing
 - the stunning of animals
 - the assessment of effective stunning
 - the shackling or hoisting of live animals
 - the bleeding of live animals
- In some countries, to apply for a CoC, a person may first have to attain a formal proficiency qualification in animal welfare at slaughter. The qualification must cover the specific operations, equipment and animal type(s) the person requires a CoC for.



Animal welfare officer

Animal welfare officer

Abattoirs must designate at least one nominated animal welfare officer (AWO), to assist with compliance with all applicable legislation, codes of practice, assurance schemes and customer requirements. In collaboration with management, the AWO must establish documented SOPs and contingency plans for routine and emergency slaughter. The AWO is responsible for supervising all operations involving live animals, from the time the animals arrive on-site. At least one AWO must be on-site at all times whilst birds are being slaughtered. The AWO, either directly or through personally-supervised staff, must take a proactive role in making frequent checks on the entire slaughter system to ensure the welfare of every bird is protected. The AWO must ensure staff understand their responsibility to take remedial action and/or to immediately inform an AWO and the veterinarian, of any sick, injured or ineffectively stunned birds. On discovery of an animal welfare concern, the AWO must have the authority to immediately take preventative and/or corrective action and to stop procedures that raise the concern. The AWO is responsible for bringing attention to welfare issues and discussing them with management. The AWO should lead an animal welfare team that includes lairage and shackling staff, slaughterpersons and senior management, and whose aim is to regularly re-assess and develop the facilities to continually improve bird welfare.

It is advisable for AWOs to attend, as necessary, a refresher training course in poultry welfare in order to be fully up-to-date with legislation and scientific and technological developments, which might assist with improving bird welfare at their place of work.

In Europe EC Regulation 1099/2009 decrees:

- Before taking up the role of AWO, an employee must attain a Certificate of Competence for every activity s/he is responsible for performing or overseeing.
- An AWO is a legal requirement if an abattoir processes $\geq 150\,000$ birds/year.
- An AWO's responsibilities must be described in the SOPs.

Further information can be read within: *The Animal Welfare Officer in the European Union*. 2012. Directorate General for Health and Consumers. European Commission. Available:

http://ec.europa.eu/dgs/health_food-safety/information_sources/docs/ahw/brochure_24102012_en.pdf



Examples of the duties of an Animal Welfare Officer

- Supervise the organisation of a lairage (including communication with the farms, catching teams and hauliers) to ensure no birds wait for an unnecessarily long time to be unloaded from a vehicle, and/or to be killed, ie oversee the delivery schedule, the associated expected arrangement of batches of transport containers in the lairage and the kill schedule, all relative to the weather conditions, the capabilities of the vehicles (passively or mechanically ventilated), any line breakdowns at the abattoir and the condition of each batch of birds (eg some may need to be fast-tracked to kill due to a welfare concern).
- Supervise the unloading, shackling, stunning, bleeding and emergency killing of birds. Ensure all staff performing these roles comply with company procedures.
- Liaise with, and routinely request feedback from, the abattoir veterinarian(s) and the food hygiene meat inspectors on causes of injuries, DOAs, rejected birds and carcass condition. Feedback may assist with identification of problems (eg atypical incidences and patterns of carcass downgrading that might relate to possible welfare issues when the animals were alive).
- Inspect equipment regularly throughout the day; check:
 - correct set-up and use of primary (eg waterbath) and back-up (eg captive-bolt) stunners
 - the electrical parameters reported by the voltmeter and ammeter are as expected and use a remote stun monitor
 - birds are effectively stunned and their necks effectively cut
 - birds remain unconscious along the entire bleed line, up to the scald tank.
- Arrange training of staff working with live birds, in accordance with the AWP, SOPs and contingency plans. Wherever possible, use exercises in problem-solving, make training practical and encourage constructive discussion and self-assessment. Provide visual feedback to enhance understanding. For example, discuss how an observed level of carcass quality may relate to the experiences of a bird whilst it was alive and passing through the slaughter process. How did those experiences contribute to the bird's welfare?
- An AWO can improve staff and bird welfare by:
 - praising staff for good attention to animal welfare and encouraging continuation of those working practices
 - constructively notifying staff on-sight of problematic working practices and explaining why; giving guidance on how to perform a procedure to benefit the welfare of the birds *and* the operator concerned.



- Ensure up-to-date records are kept of:
 - daily inspections of the performance of the shackle line, primary and back-up stunners and neck cutting, against clear pass/fail criteria. The key parameters (including appropriate, fully descriptive units) for all types of routine and back-up stunning and killing equipment used, must be readily available for internal or external inspection (EFSA, 2006)
 - all corrective action taken to improve animal welfare throughout the live bird areas. (In Europe, this is a legal requirement of EC Regulation 1099/2009.)
 - setting up, cleaning, adjustment, calibration and maintenance of the entire slaughter system, including the back-up stunner(s)
 - staff training for routine slaughter and emergency killing.



Appendix I - example SOP

Standard Operating Procedure - electrical waterbath stunning

Objective: stun bird humanely and effectively by exposing a bird's head and body to a current generating a generalised epileptic form on the EEG, rendering the bird immediately unconscious and insensible to fear and pain until death.

Procedure:

1. At the start of the day, the AWO (or other officially-nominated supervisor) should check/record that the following equipment is appropriate for the bird type and is not damaged or showing signs that might indicate compromised function: the shackle washer, shackles, line speed, submerged electrode, twin earthed rubbing bars, breast contact system, entry ramp, waterbath panels, waterbath emergency access points, water level, waterbath height-adjustment mechanism, stunner control panel and meters, automated neck cutter blades and knife blades. Check no obstacles are positioned in the way of the shackle line (which might disturb shackled birds or hinder staff who might need to access the line in an emergency).
2. The AWO should check the waterbath is set to provide the intended key parameters for stunning, eg waveform, frequency, duty cycle, voltage. Salt should not be added to the water unless *absolutely necessary*; if salt is added, the resultant salinity/conductivity must be continuously maintained and the conductivity of the water and the current must be checked at least every 20 minutes and the voltage adjusted as-appropriate.
3. The AWO should prepare a remote stun monitor for entry to each waterbath, to test the current received. Program the stun monitor with a resistance that is likely to represent the upper average resistance that will be encountered for that bird type. The voltage should be increased until the stun monitor reports a current amplitude that equals or exceeds the desired/recommended or legal requirement per bird.
4. The AWO should ensure personnel responsible for assessing the effectiveness of stunning and for performing the follow-up killing method (ie neck cutting) are ready for stunning to begin and there are spare knives and a back-up stunner (eg captive-bolt) immediately available with sufficient suitable power sources for the bird type (eg age, sex, breed, species).
5. The AWO (or other nominated person) should: ensure shacklers are in a stable, comfortable stance/position; observe shacklers (particularly new personnel) to ensure they gently handle and appropriately shackle healthy, uninjured birds, in a manner appropriate for the species; ensure unhealthy or injured birds are gently handled and immediately humanely killed using the back-up stun/kill method (and not subjected to routine shackling and waterbath stunning).
6. Nearby personnel should ensure birds do not receive pre-stun shocks. Each bird's cranium must be immediately submerged in the electrified water. Ensure each bird's shackle is in continuous contact with the twin earthed rubbing bars during passage through the waterbath (particularly at the start of stunning).
7. Immediately after birds exit a waterbath, nearby personnel should examine the birds for signs of ineffective stunning. Signs of ineffective stunning include:
 - presence of rhythmic breathing
 - presence of a corneal reflex
 - presence of tension in muscles controlling jaw, neck
 - presence of spontaneous blinkingWhen effectively stunned, poultry may convulse (body tremors and mild, rapid wing contractions). Absence of these convulsions may indicate an ineffective stun; the bird should be rapidly re-examined and, if necessary, stunned immediately using back-up equipment.
8. If a bird is ineffectively stunned, apply the back-up stun/kill method (eg captive-bolt) whilst the bird is in its shackle. Ascertain why the bird failed to be stunned by the waterbath and take corrective action to prevent it occurring again (ie notify the AWO of ineffective stunning and the suspected reason). The AWO should record this information for each failed/back-up stun and should review the records regularly.
9. The AWO should regularly observe each slaughterperson and record the number of birds they either fail to identify as ineffectively stunned, or identify as ineffectively stunned but fail to take appropriate corrective action or to inform the relevant supervisor of the incident (EUWeINet, 2013b).



Appendix I - example SOP

10. After confirming effective stunning, ensure each bird immediately receives a ventral neck cut within 15 seconds of standard frequency (eg 50 Hz) electrical stunning and within 10 seconds of high frequency stunning. A ventral neck cut shall be used to ensure any birds that do not experience cardiac arrest have a maximal rate of blood loss and to enable the effectiveness of neck cutting to be easily verified. Observe ANCs and slaughterpersons (particularly new personnel) to ensure each bird displays an upside-down V-shaped pattern of high-pressure blood loss immediately after cutting, indicating both carotid arteries are severed. (For each ANC and/or slaughterperson, the AWO should also regularly inspect neck cuts to confirm, record and review, the proportion of birds with both carotid arteries severed.)
11. The AWO should regularly record the number of birds a slaughterperson either fails to identify as ineffectively cut, or identifies as ineffectively cut but fails to take corrective action (eg fails to cut again or, in the case of ANCs, fails to inform the relevant supervisor of the problem) (EUWeINet, 2013b).
12. After birds have bled for 3 minutes, confirm the birds' death (eg absence of a corneal reflex and absence of rhythmic breathing) prior to further processing.
13. At the end of the day's kill, the AWO (or other nominated persons) should download the key parameter data from the waterbath control panel, clean the waterbath and disassemble and clean the back-up stunner, inspect all stunners' components and assess if the stunners may require replacement parts and/or servicing. After cleaning, where possible, test each stunner to ensure it meets minimum requirements for the relevant bird type. Calibrate the waterbath stunner control panel and remote stun monitor every six months. Records of these activities must be kept and regularly reviewed.

Key operational parameters - EXAMPLE ONLY (parameters may vary in practice)

The table below indicates the parameters used when slaughtering the poultry species accepted by the abattoir.

The total voltage supplied to a waterbath is an estimate because the voltage will need to be monitored and adjusted (as-appropriate) daily or more frequently, to account for variation in the resistance of the circuit.

The estimated voltages for broiler chickens are based on the upper average resistances of females, to increase the likelihood that both sexes receive the minimum desired current amplitude when stunned in mixed-sex groups.

Key parameters for each bird type	Broiler chickens	Female broiler turkeys
Maximum conscious shackling duration:	1 minute	2 minutes
Number of phases of electricity applied by the stunner:	Single-phase	Single-phase
Waveform:	Sinusoidal AC	Sinusoidal AC
Maximum frequency (for the current specified):	60 Hertz	50 Hertz
Period:	16.67 milliseconds	20 milliseconds
Pulse width:	16.67 milliseconds	20 milliseconds
Duty cycle:	100%	100%
Estimated resistance of bird type:	1600 Ω	2300 Ω
Estimated minimum voltage:	176 V RMS	575 V RMS
Maximum number of birds in water at once:	10 birds	5 birds
Minimum required current per bird:	110 mA RMS	250 mA RMS
Minimum required total current to waterbath:	1.10 A RMS	1.25 A RMS
Duration of electrical application:	15 seconds	10 seconds



Appendix II - example SOP

Standard Operating Procedure - captive-bolt stunning

Objective: stun bird humanely and effectively by rapid transfer of impact energy to the brain, provoking severe damage and rendering the bird immediately unconscious and insensible to fear and pain until death is caused.

Procedure:

1. Check the captive-bolt for damage or signs that might indicate compromised function.
2. Ensure personnel responsible for performing the follow-up killing method (eg bleeding, cervical dislocation) are ready and there is back-up equipment immediately available with sufficient [and spare] suitable power sources for the number, species and bird type (eg age, sex, breed).
3. Ensure the bolt is in its correct pre-firing position within the barrel of the stunner.
4. Load/prepare the necessary power source (eg cartridge ammunition, air compressor or gas cylinder) for the captive-bolt stunner, according to the manufacturer's instructions. Use the correct grade of power source (eg cartridge type or air pressure); too little energy may not stun the bird, too much energy may damage the stunner.
5. Ensure you are in a stable, comfortable stance/position. Gently restrain the bird if necessary, in a manner appropriate for the species and in accordance with the manufacturer's instructions for the restrainer and stunner. Ensure the bird's head is in a position where an accurate shot can be made.
6. Stun the bird in the position indicated and according to the manufacturer's instructions. Ensure stunner muzzle is in contact with the bird's head when fired. In most cases, the muzzle should be at a right-angle to the head.
7. Immediately after application, examine the bird for signs of ineffective stunning. Signs include:
 - failure to immediately collapse
 - presence of rhythmic breathing
 - presence of a corneal reflex
 - presence of tension in muscles controlling jawWhen effectively stunned, poultry may convulse (flap) almost immediately and severely (read HSA specialist publications for further details). Absence of these convulsions may indicate an ineffective stun; the bird should be rapidly re-examined and, if necessary, stunned immediately.
8. If a bird is ineffectively stunned, it is essential that a repeat shot is placed to avoid the immediate area of the first shot. If the first shot was off-target, aim to place the second shot on-target. If the first shot was on-target, particularly for small poultry (eg chickens), placing an [effective] second shot may not be possible; an alternative back-up stun/killing method should be used. Ascertain why a first shot failed, record repeat shots and review this information regularly.
9. Ensure each bird is then immediately killed (eg by bleeding). If one operator is responsible for performing stunning and killing, s/he must complete restraint, stunning and killing of one bird before performing any of those procedures on another bird. Confirm the bird's death (eg sustained absence of corneal reflex and rhythmic breathing for at least three minutes).
10. At the end of the day's kill, disassemble the captive-bolt to clean it, remove carbon and silica deposits and to inspect components and assess if the stunner may require replacement parts and/or servicing. After cleaning, where possible, the AWO (or other nominated person) should perform a bolt velocity test to ensure it meets minimum requirements for the relevant bird type. Records of these activities must be kept by the AWO and regularly reviewed.



Appendix II - example SOP

Power source

The required grade of the power source (eg cartridge type or air pressure) may vary with the manufacturer and model (eg calibre) of the captive-bolt stunner. Some information (eg cartridge grain, bolt velocity) is not easily obtainable and there is no international standard colour system used by all manufacturers to denote cartridge strength. Therefore, always follow the manufacturer's instructions.

Bolt length, diameter, shape

These dimensions may vary with manufacturer and model. Always follow the manufacturer's instructions.

Maximum stun-to-cut/kill interval

Always kill, or sever both carotid arteries or the vessels from which they arise, as soon as possible after stunning and preferably within 15 seconds.

Example of a procedure and the key parameters for stunning poultry using a Cash Poultry Killer captive-bolt stunner:

Stunning poultry: mechanical percussive devices

Restraint

Power source

Information based on Accles & Shelvoke Ltd Cash :22 Poultry Killer

	Cash E 0.22 rim-fire (1 grain)	Cash E 0.22 rim-fire (1 grain)	Cash E 0.22 rim-fire (1 grain)	Cash E 0.22 rim-fire (1 grain)
	120 psi	135 psi	135 psi	135 psi
			Poult:	
			60psi	

Application

- Restrain head by lightly holding the beak.
- Position muzzle on the highest point of the head, between the eye and the ear, and on the midline.
- Aim straight down through the head, and at right angles to the top of the head.
- On impact, allow the head to be propelled from your hand. Do not hold onto head after firing.

Assessment

Signs of an effective stun

- Uncontrolled severe wing flapping
- No rhythmic breathing immediately after shot
- No control over neck movement
- Leg flexion and extension
- Eyes have fixed, glazed expression

→ Bleed the bird or dislocate the neck

Signs of an ineffective stun

- Intermittent, or absence of, flapping
- Rhythmic breathing immediately after shot
- Ability to control neck
- Escape behaviour
- Vocalisation

→ Apply a back-up stunning or killing method

For additional information, view HSA publications at www.hsa.org.uk or contact:

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Additional notes:

- This guidance must be read in conjunction with all applicable legislation, eg EC Reg 1099/2009
- Operator must have any necessary licences and/or certificates, if required
- Refer to other HSA guidance for further detail and for restraint of birds and killing methods
- Never point the muzzle of a stunner at anything you do not intend to stun, nor leave it unattended



Ammeter	a device for measuring current flow
Amp, milli-amp (A, mA)	unit of current flow (1 A = 1000 mA)
Amplitude	amount or magnitude, eg of current or voltage
Analogue meter	available with either a needle or digital display. Meter may have RMS written on it but it will not be true RMS; on the DC setting the meter provides the average voltage and on the AC setting it provides 111% of the rectified average voltage (which, for a sine waveform, is the same as RMS). For a pDC waveform with 50% duty cycle, the RMS is 141% of the average DC reading.
Apnoea	absence of breathing
Cardiac arrest	the heart stops pumping
Cloaca	common exit, from the body, of the intestinal, urinary and reproductive tracts
Conductivity	a quantification of the ability of a substance (eg water) to conduct electricity. Measured in Siemens/metre (S/m)
Conductor	a substance allowing the flow of electrical current
Current (I)	flow of electricity through an object
Duty cycle	the duration of time that the current is on (the 'mark' or pulse width), as a fraction of the duration of one period (ie one complete cycle of the waveform, incorporating the durations of both the 'current on' (mark) and 'current off' (the 'space') components), and expressed as a percentage, eg $(\text{pulse width} \div \text{period}) \times 100$
Electrodes	conductors between which current flows
Electroencephalogram EEG (or ECoG)	graphical trace displaying the biological electrical activity of the brain, specifically the voltage fluctuations resulting from current flows within neurons of the brain. Trace obtained by positioning recording electrodes on scalp (or brain)
Electroimmobilise	cause paralysis by application of electric current
Electronarcosis	render unconscious by application of electric current



Exsanguination	draining a body of blood
Fibrillate	quivering caused by unco-ordinated contraction of fibrils
Frequency	how many times, in one second, a complete cycle of a waveform is repeated. Frequency (Hz) = $1000 \div \text{period (milliseconds)}$
Hazard	any factor with the potential to cause an adverse effect on animal welfare (SLU, 2009)
Hertz (Hz)	unit of frequency, cycles per second
Impedance	electrical resistance to alternating current
Innervated	supplied with nerves
Insensible	unable to perceive external stimuli, eg unable to experience fear or pain (EFSA, 2013a)
Insulator	a substance that obstructs the flow of electrical current
Ischaemia	inadequate supply of blood to an organ
Keratinization	the conversion of epidermal (skin) cells into keratin, a harder, lower-moisture-content material, eg scales
Kill	any intentionally induced process which causes the death of an animal
Nictitating membrane	third eyelid. When the surface of the eye is gently touched, as a reflex, the 'cloudy' nictitating membrane moves across the eye, from the rostral corner of the eye to the caudal corner (ie in the direction from the beak towards the body)
Ohm (Ω)	unit of resistance (R)
Palpebral (blink) reflex	when a corner of the eye (or edge of the eyelids) are gently touched, the eye closes by bringing together the dorsal (upper) and ventral (lower) eyelids
Paralysis	impairment, or loss, of voluntary control of muscles, without loss of consciousness



Glossary

Peak current	with regard to pDC, peak = $\frac{\text{average current} \times \text{period}}{\text{mark}}$
Period	the duration of time taken to complete one waveform. Period (milliseconds) = $1000 \div \text{frequency (Hz)}$
Periosteum	a dense layer of vascular connective tissue enveloping the bones except at the surfaces of the joints
Recovery	return to consciousness, with potential ability to experience fear and pain
Resistance (R)	properties of a substance that limit current flow. Resistors arranged in parallel in a circuit (eg birds in a constant voltage waterbath) will always have a total resistance that is less than that of any single resistor (bird) in the circuit (Bilgili, 1992). The total resistance of all the birds in the water at any given time can be estimated using the calculation below: $\frac{1}{R} = \frac{\text{number of birds in water at any given time}}{\text{the average resistance of that bird type}}$
Risk	a function of the probability of an adverse effect and the severity of that effect, consequent to a hazard for animal welfare (SLU, 2009)
Root mean square (RMS)	a measure of the amplitude of a current or voltage, which may be slightly less than the peak current or voltage. The calculation below can convert peak values to RMS for pure forms of sine waves. (The same calculation may not apply to distorted wave shapes. A digital 'AC+DC true-RMS' meter may be a useful tool for measuring RMS values for any waveform; always consult an electrical engineer for advice.) For sine AC: $I_{\text{RMS}} = 0.707 \times I_{\text{peak}}$ For square AC: $I_{\text{RMS}} = I_{\text{peak}}$
Shunt	a lower-resistance pathway that current will preferentially flow through
Sinusoidal (sine)	smooth undulating wave
Slaughter (in Europe)	killing animals [intended] for human consumption



Stun	to render unconscious and therefore insensible to fear and pain
Tonic	a physical seizure where the muscles experience tetanus (rigidity). An inverted bird's neck may be arched backwards so it hangs parallel with the ground and the wings may be held tightly against, or tucked into, the body (Figure 29Aiii). The wings may display small, quick muscular contractions (Prinz, 2009; EFSA, 2013a)
True RMS meter	on the DC setting the meter provides the average voltage. On the RMS setting the meter provides the standard deviation of the voltage, which is only equivalent to the RMS if the average is zero volts; the formula the meter uses is: $\text{RMS}^2 = \text{average}^2 + \text{standard deviation}^2$
Ventral neck cut (VNC)	a transverse cut across the underside of the neck (throat), to sever both carotid arteries and both jugular veins
Ventricular fibrillation	rapid, uncontrolled, unco-ordinated contractions of the ventricles of the heart, leading to cardiac arrest
Volt (V)	unit of electrical pressure
Voltage	the driving force or electrical pressure
Voltmeter	a device for measuring voltage
Waveform	the shape of one complete cycle of an electrical current or voltage
Weight/volume %	measure of solute (eg salt) per 100 ml of a solution (eg saline) eg $w/v\% = 100 \times \frac{\text{salt (grammes)}}{\text{volume of saline solution (ml)}}$ eg a waterbath holding 100 litres of saline at a 0.1 w/v % NaCl will contain: $(0.1 \div 100) \times 100\,000 = 100 \text{ g salt}$



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Useful contacts and publications

Remote stun monitors

- Poultry Stunning Bath Current Monitor (PSM), AGL Consultancy Ltd.
<http://aglconsultancy.com/index.htm>
- Reesink Special Products BV, Argonstraat 156, 2718 SP Zoetermeer, Netherlands www.rspbv.nl/

Measuring current through a live bird in an electrical waterbath circuit

Paul Berry Technical Ltd Stunner Evaluation Service. Email: paul.berry@pbtech.co.uk

Sample size calculation tool for monitoring stunning at slaughter, EFSA

EFSA, 2013. *EFSA Sample Size and Stunning (EFSA SStun model), version 1.0 – application interface developed by EFSA*. (Application interface can be made available on request to sas@efsa.europa.eu) A tool developed by the European Food Safety Authority SAS Unit to provide all relevant stakeholders, including Food Business Operators, with a simple and user-friendly software application to enable them to estimate: i) sample size needed, given a fixed failure rate considered acceptable; ii) expected failure rate, given the sample size, when monitoring stunning at slaughter. EFSA (2013b): please note that [the EFSA 2013b] document has been established for information and consultation purposes only and does not necessarily constitute the views of the Commission as it has not been adopted or in any way approved by the European Commission.

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Agriculture and Horticulture Development Board (AHDB) www.ahdb.org.uk

A non-departmental public body which offers services, information, advice and leadership to all involved in the agriculture and food sectors.

Animal Welfare Training www.awtraining.com

Professional Welfare Officer training, education and consultancy for the meat industry worldwide.

British Veterinary Association www.bva.co.uk

The national representative body for the veterinary profession.

Defra www.gov.uk/animal-welfare

Government department responsible for animal welfare at slaughter.

Division of Food Animal Science, School of Veterinary Sciences, University of Bristol

www.bristol.ac.uk/vetscience/

Animal Welfare Officer training: www.awotraining.com/

Scientific research group investigating animal welfare at slaughter. Provides training and consultancy.

Food Standards Agency www.food.gov.uk/

Responsible for enforcing hygiene and animal welfare in EU-approved abattoirs throughout the UK.

Meat and Livestock Commercial Services Ltd. (MLCSL) www.mlcsl.co.uk/

Provides data, advice, logistics and inspection services to the meat and livestock industry and the Defra family, on a commercial basis. The MLCSL is the commercial arm of AHDB.

Meat Training Council www.meattraining.org.uk

Provides information on colleges, universities, trainers' courses and qualifications, including S/NVQ. Gives advice on training priorities and plans financial advice for training and development.

TSO (The Stationary Office) www.tso.co.uk/ & www.tsoshop.co.uk/

Contact for copies of UK legislation.

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Technical Information Posters (TIPs) (available as A3 or A4 and laminated):

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DVDs: *Poultry Welfare – Taking Responsibility - catching, transport and slaughter*

Emergency Slaughter

Codes of Practice: *Code of Practice for the Disposal of Chicks in Hatcheries*

Technical Notes: various titles available to download free-of-charge at www.hsa.org.uk



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ISBN 978-1-871561-44-9